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# TROPICAL AGRICULTURIST

AGRICULTURAL JOURNAL OF CEYLON

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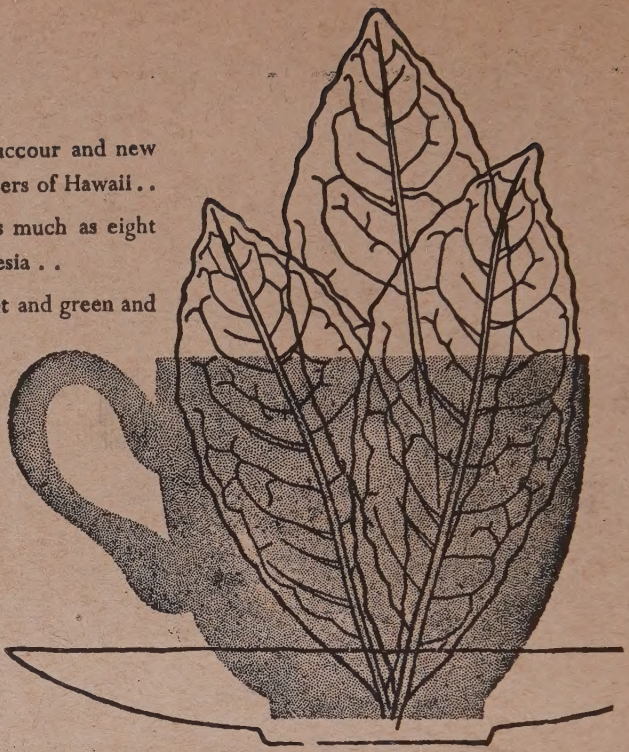

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# TROPICAL AGRICULTURIST

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*Edited by*

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CEYLON DEPARTMENT OF AGRICULTURE

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# EDITORIAL

## Self-Sufficiency in Rice

As recently as 1949, the Government " Statistical Abstract " estimated Ceylon's average acre yield of paddy at 14 bushels. This fantastic figure, which was Ceylon's official yield estimate less than a decade ago and which placed this country's rice yields among the lowest in the world, was derived by processing a series of guesstimates ultimately furnished by the grower himself. The low estimate that the peasant customarily provided of the yield of his field was blamed on various factors including the share system of tenancy and belief in the evil eye.

Credit for providing the first statistically satisfactory estimate of rice yields in this country must go to the Department of Agriculture : a random sample survey made by the Department's Botanist in 1949, on 49,000 acres in the Kandy, Kegalle and Ratnapura Districts, placed the average paddy yield in that area in the *yala* season, at 27.3 bushels per acre with a standard error of 2.5 per cent. An F. A. O. Statistician subsequently confirmed the correctness of the Department's conclusions. The rise in yields since 1949 has been steady but snail-slow. The average acre yield over Ceylon's total rice area was 33 bushels in *maha* 1956-57, and 32 bushels in *yala* 1957.

Ceylon's population in 1955 was estimated at 8,723,400. Using the 'low' population projection prepared by the Department of Census and Statistics on the basis of a persistence of the present mortality rates, and of a decline in the crude birth rate to 35.0 over the period 1955-65, and making allowance for emigration at the rate of 0.2 per cent, one may assume that at the end of the 5-year period commencing 1958, Ceylon's population would approximate 10 millions. Per capita consumption of rice over the period 1951-55 averaged 198 lb. per annum. The year 1953 was exceptional : reduction of the rice subsidy in that year depressed per capita consumption to 165 lb. per annum. Exclusion of the 1953 value raises per capita consumption to 206 lb. per annum. (Clarenbach, 1958). For purposes of the present calculation, the figure of 198 lb. per capita per annum has been used.

The milling out-turn by weight of Ceylon paddies is 57-71 per cent. for raw rice, and 62-72 per cent. for parboiled rice. The bushel weight of unawned paddies is rarely under 44 lb. and occasionally rises to over 50 lb. For the present calculations, the estimates adopted by the Department of Census and Statistics have been used, viz : a milling out-turn of 68 per cent., and a bushel weight of 45 lb. On this basis, and at a per capita consumption of 198 lb. per annum, the requirements of a population of 10 millions would be 64.7 million bushels of paddy.

3——J. N. B 4892—(7/58)

The physical asweddumized acreage in 1954-55 was 1,031,611 acres. The aggregate sown acreage in *maha* and *yala* in this year amounted to 1,346,824 of which 40 per cent. was single-cropped and 60 per cent. was double-cropped. The extent unsown in the two seasons was 716,398. The harvested acreage was 1,092,000.

It is reasonable to assume that, in normal years, an extent of not less than 1.3 million acres would be sown in the two seasons, and that 85 per cent. of this acreage, viz : 1.1 million acres, would be harvested. To provide the estimated requirement of 64.7 million bushels of paddy, an average yield of *58.9 bushels per acre* would be needed.

In his recent study of rice production problems in this country, Dr. F. A. Clarenbach, U. N. Expert attached to the Planning Secretariat, makes the disturbing deduction that "self-sufficiency in rice is highly improbable or well beyond the range of reasonable possibility for Ceylon in the next two or three decades—barring near-miracles of science such as the application of new methods with low-cost nuclear power for construction of irrigation and flood control works and revolutionary developments in agrobiology and the technology of rice production." Yield projections provide the main basis of Dr. Clarenbach's argument. Even when his calculations were made at the "high" yield increase rate of 1.5 bu. per acre, the gap between requirements and production was depressingly wide. Dr. Clarenbach's deductions must be blamed largely on the defective data made available to him. A critical analysis of yield potentials leave little room for his pessimism. The regression of acre yields on time is likely to be logarithmic at least in the early stages, and not rectilinear as Dr. Clarenbach assumes. The effects of improved practices cumulate geometrically, not arithmetically, and the simultaneous adoption of the whole range of improved techniques would find expression in prodigious yield increases.

In the final analysis, the yield problem in rice resolves into—

(*a*) the use of optimum fertilizer dressings,

(*b*) the use of high-response, blast-resistant varieties that permit the most efficient exploitation of fertilizers, and

(*c*) the elimination of factors that obstruct efficient fertilizer action, e.g., weed infestation and precarious water supply.

Negative factors, e.g., the elimination of pest hazards, of course, demand attention, but it is evident that the rational and intensive use of fertilizers provides the most fruitful method of yield increase in rice.

The chief factors that have limited efficient fertilizer exploitation in the past have been the delay (*a*) in the mapping of rice soils for fertilizer response, and (*b*) in the breeding of high-response, blast-resistant strains. The Department is rapidly remedying both these deficiencies.

A study of the nitrogen response in rice reveals tremendous potentialities for yield increase. When the supply of phosphate is adequate, and high-response varieties are used, the curve of response rises continuously to a maximum at about 60 lb. nitrogen per acre. The yield increase per lb. of nitrogen applied ranges from 9 lb. to 24 lb. paddy per acre, depending on the fertilizer response of the variety and the operation of limiting factors. It is anticipated that on nearly the totality of the 26,000 acres of asweddumized land that compose the major irrigation schemes, yield increases of 10-12 bushels would be possible with 40 lb. of applied nitrogen per acre if the right varieties are used. Moreover, even at present in certain areas, average yields approximate to the value needed for self-sufficiency. Acre yields of 55 and 58 bushels have been recorded over the total cultivated extent in the Polonnaruwa and Kegalle Districts. If these are achieved in the rest of the Island's rice acreage, self-sufficiency becomes a reality.

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# STUDIES ON THE NUTRIENT STATUS OF SOME COCONUT SOILS IN CEYLON

## 3. THE FOREST SOIL AT "AMBAKELLE"

### (A) Preliminary Experiments

By T. B. PALTRIDGE and BERYL SALMOND
(Coconut Research Institute, Ceylon)

## 1. INTRODUCTION

This paper is one of a series recording data from experiments with some of the more important coconut soils in Ceylon. Those experiments were designed to give basic information on the nutrient status of each soil, with a view to more effective use of fertilizers on coconuts, and to correction of nutrient deficiencies that might be a limiting factor in the growth and selection of desirable pasture plants. The type of experiment and techniques employed have all been described in a previous article (*Tropical Agriculturist*. Vol. CXIII, 1957).

Ambakelle is situated in the Chilaw District of Ceylon. It is on a coastal plain, approximately four miles from the western coastline and 52 miles north of Colombo. The natural vegetation is a tropical forest, but in 1955 a small area of 200 acres was cleared and has since been developed as an 'Isolated Seed Garden', where new varieties of coconut can be grown without serious risk of cross-pollination with other varieties, or with those used for commercial crops in that district. Information on the nutrient status of that soil—which may be typical of comparatively large areas in the dry zone—is of obvious importance to the overall program of C. R. I. research.

The soil at Ambakelle is a light sandy loam generally about five feet in depth overlying a layer of rounded pebbles which is itself about two feet in thickness. Beneath those pebbles is a hard-pan 6 to 12 inches thick and the sub-soil is a stiff brownish clay. In order to avoid any complication from admixture of ash or forest debris after clearing, the soil used in these experiments was collected from a number of locations within the undisturbed forest. Those samples were then transported to the laboratory, thoroughly

mixed, and after removal of any coarser vegetable matter (leaves, stems and larger roots) that ' soil ' was stored in a large wooden bin, thereby providing uniform material for use in a number of pot experiments.

The pots were all 6 inch polysterene flower pots :—each containing approximately 2,000 gms. (dry weight) of soil. The response to any nutrient was measured in terms of the dry weight of plants grown in every pot. All pots were watered daily, their water content being brought to a constant level (85 per cent. field capacity) by weight. The water was filtered, passed through a commercial water softener, distilled and re-distilled before use. The final distillation was in ' pyrex ' glassware.

The test plants were a perennial pasture grass (*Paspalum commersonii* Lam.) and two legumes (*Phaseolus lathyroides* L. and *Medicago sativa* L.)

## 2. EXPERIMENTAL

### A. Experiment 1

(1) **Objective.**—To measure the effect of major nutrients (N.P.K.Ca. and Mg.), and of ' X ' (a mixture of Fe. Cu. Zu. and Mn.) on the yield of *Paspalum commersonii* growing on forest soil from Ambakelle.

(2) **Design and Procedure.**—This was a $2^6$ factorial experiment with only one replicate of each treatment. Calcium was applied as $CaCO_3$ (10 cwt/acre, mixed with the upper $1\frac{1}{2}$ inches of soil); all other nutrients were applied in solution, and in forms and doses enumerated in Table I.

TABLE I.—*Forms and rates of fertilizer applied in Experiment 1*

| *Designation* | *Chemical* | *Rate of Application/Acre* |
|---|---|---|
| $N_5$ | $(NH_4)_2SO_4$ | 5 cwt. ≡ 118 lb. N. + 135 lb. S. |
| $P_3$ | $NaH_2PO_4.2H_2O$ | 3 cwt. ≡ 67 lb. P. + 49 lb. Na. |
| $K_3$ | $K_2SO_4$ | 3 cwt. ≡ 150 lb. K. + 70 lb. S. |
| $Mg1\frac{1}{2}$ | $MgSO_4.7H_2O$ | $1\frac{1}{2}$cwt. ≡ 18 lb. Mg. + 21 lb. S. |
| $Fe_{14}$ | $FeSO_4.7H_2O$ | 14 lb. ≡ 2·8 lb. Fe. + 1·6 lb. S. |
| $Cu_{14}$ | $CuSO_4.5H_2O$ | 14 lb. ≡ 3·6 lb. Cu. + 1·8 lb. S. |
| $Zn_{14}$ | $ZnSO_4.7H_2O$ | 14 lb. ≡ 3·0 lb. Zn. + 1·6 lb. S. |
| $Mn_{14}$ | $MnSO_4.4H_2O$ | 14 lb. ≡ 3·5 lb. Mn. + 2·0 lb. S. |

The *Paspalum* was planted on 19th January, 1957, and harvested four times, viz.—on 11th March, 4th April, 8th May and 5th June, 1957. Additional nutrients were applied as follows:—

5th March, 1957—3 cwt./acre $K_2SO_4$ was applied to all pots with added K. Total dose then ≡ 300 lb./acre of K.

7th March, 1957—5 cwt. acre $(NH_4)_2SO_4$ was applied to all pots with added N. Total dose then ≡ 236 lb./acre of N.

3rd April, 1957—1½ cwt. acre $K_2SO_4$ was applied to all pots with added K. Total dose then ≡ 375 lb./acre of K.

2½ cwt./acre $(NH_4)_2\ SO_4$ was applied to all pots with added N. Total dose then ≡ 295 lb./acre of N.

22nd April, 1957—3 cwt. acre $NaH_2PO_4.2H_2O$ was applied to all pots with added P. Total dose then ≡ 134 lb./acre of P.

25th April, 1957—2½ cwt. acre $(NH_4)_2SO_4$ was applied to all pots with added N. Total dose then ≡ 354 lb./acre of N.

9th May, 1957—1½ cwt. acre of $K_2SO_4$ was applied to all pots with added K. Total dose then ≡ 450 lb./acre of K.

15th May, 1957—2½ cwt. acre $(NH_4)_2SO_4$ was applied to all pots with added N. Total dose then ≡ 413 lb./acre of N.

The full dosage for pots receiving N.P.K. and Ca. was therefore—

| | | |
|---|---|---|
| 17·5 —wt./acre $(NH_4)_2SO_4$ | — | 413 lb./acre of N. |
| 9·0 cwt./acre $K_2SO_4$ | — | 450 lb./acre of K. |
| 6·0 cwt./acre $NaH_2PO_4 2H_2O$ | — | 134 lb./acre of P. |
| 10·0 cwt./acre $CaCO_3$ | — | 448 lb./acre of Ca. |

(iii) **Results.**—Magnesium and 'X' had no significant effect on yields in any harvest, and mean yields for four replicates (nil, Mg., X and MgX) are recorded in Table II.

TABLE II. *Experiment 1 showing mean yields and level of significance for all treatments affecting the yield of* Paspalum commersonii *in four successive harvests.* (N.B. *Significance at 5 per cent not recorded.*)

| *Harvest* | *Treatment* | *Nil* | *N.* | *P.* | *N.P.* | *Effective Treatments and Level of Significance Per cent.* |
|---|---|---|---|---|---|---|
| (1) Age 51 Days | nil nil | 0·95 | 1·56 | 1·91 | 7·82 | K. (0·1) |
| | K. | 0·62 | 2·31 | 2·23 | 8·49 | P. (0·1) |
| | | | | | | N. (0·1) |
| | Ca. nil | 0·69 | 1·04 | 1·88 | 6·39 | HARV. (0·1) |
| | K. | 0·72 | 1·98 | 1·97 | 6·91 | |
| | | | | | | K.P. (0·1) |
| (2) Age 75 Days | nil nil | 1·19 | 2·26 | 1·18 | 3·63 | K.N. (0·1) |
| | K. | 1·27 | 2·89 | 1·07 | 7·61 | P.N. (0·1) |
| | | | | | | K.H. (0·1) |
| | Ca. nil | 1·33 | 2·00 | 1·22 | 4·06 | P.H. (0·1) |
| | K. | 1·20 | 2·99 | 1·04 | 7·05 | N.H. (0·1) |
| | | | | | | Ca.H. (0·1) |
| (3) Age 109 Days | nil nil | 1·55 | 4·85 | 1·91 | 2·55 | K.P.N. (0·1) |
| | K. | 1·45 | 5·37 | 1·69 | 12·01 | K.P.H. (0·1) |
| | | | | | | K.N.H. (0·1) |
| | Ca. nil | 1·67 | 4·78 | 1·53 | 3·97 | P.N.H. (0·1) |
| | K. | 1·44 | 5·45 | 2·03 | 11·65 | N.Ca.H (0·1) |
| | | | | | | K.P.N.H. (0·1) |
| (4) Age 147 Days | nil nil | 0·88 | 0·11 | 0·98 | 0·02 | |
| | K. | 0·70 | 1·13 | 0·63 | 4·66 | |
| | Ca. nil | 0·84 | 1·46 | 0·84 | 0·15 | |
| | K. | 0·78 | 1·61 | 0·68 | 5·64 | |

The data show that in all four harvests N. P. and K. together had a very big effect on yield. The same three nutrients alone or in other combinations had a somewhat smaller effect. Calcium had very little effect, except during the first harvest :—when it was responsible for some depression in yield. That pattern of responses was consistent over all four harvests. Mean yields for two replicates (' nil ' and Mg.) and for 32 treatments are shown diagrammatically in Fig. 1 and 2.

(a) **First Harvest.** In the first harvest N.-alone increased yields by approximately 64 per cent. ; N.P., N.K. and N.P.K. gave increments of 723, 143 and 794 per cent. respectively. K.-alone had no significant effect ; P.-alone, and P.K. gave increments of 101 and 135 per cent.

*Experiment 1 –Diagram showing mean yield for each of 32 treatments in four successive harvests* Paspalum commersonii

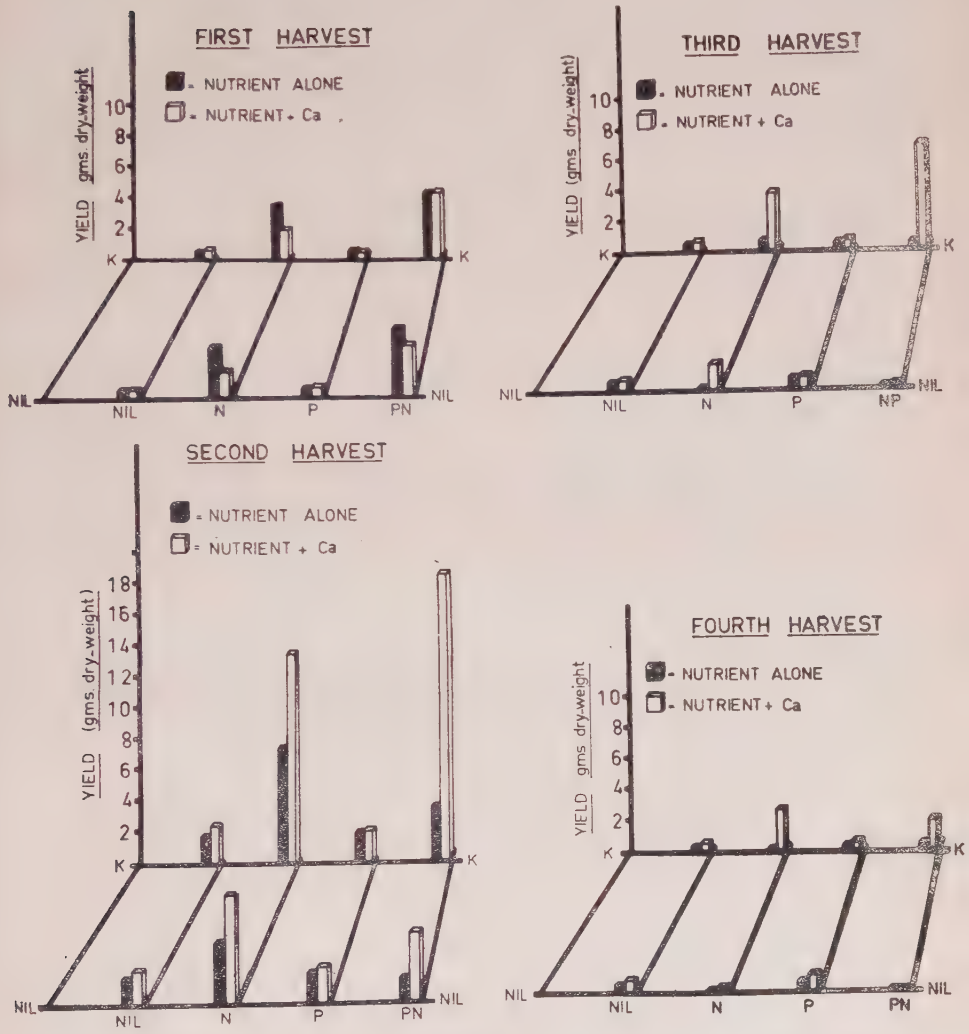


Fig. 1

Calcium was in all cases responsible for some depression in yield, and on a basis of 100 for each of eight N.P.K. treatments, the mean relative yield for Ca. was 85 $\pm$ 5·4.

(b) **Second Harvest.**—In the second harvest, N.-alone increased mean yields by 90 per cent. ; N.P., N.K. and N.P.K. gave increments of 205, 144, and 540 per cent., respectively. P.-alone, K.-alone and P.K. had no significant effect on yield.

Calcium had no significant effect on yield in any combination with N., P. or K.

(c) **Third Harvest.**—In the third harvest N., N.K., N.P. and N.P.K. gave increments of 213, 246, 65 and 675 per cent. respectively ; K.-alone and P.-alone had no significant effect ; P.K. gave a small increment of 23 per cent.

Calcium had no significant effect.

(d) **Fourth Harvest.**—In the forth harvest, and with N.-alone, or with N.P., three out of four plants died ; N.K. increased mean yields by 28 per cent., N.P.K. by 430 per cent ; P.-alone, K.-alone and P.K. had no beneficial effect (increment of 11 per cent. and decrements of 20 and 28 per cent. respectively.)

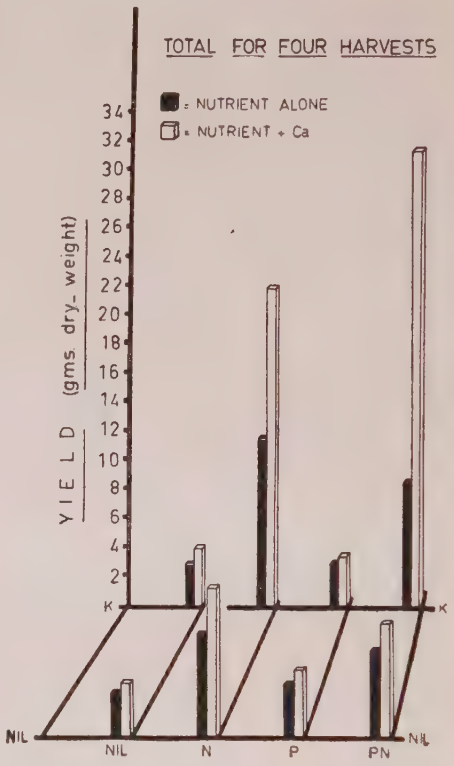


Fig. 2

*Experiment 1—Diagram showing cumulative yields from four successive harvests of* Paspalum commersonii

Calcium had no significant effect on yield.

(iv) **Discussion**—The data from Experiment 1 have shown that plants growing on this soil would suffer from an acute deficiency of N.P. and K., but unlike the lateritic soils at ' Bandirippuwa ' (see C.R.I., Bulletins 11, 12 and 13), and except for an increasingly acute deficiency of K., the pattern of responses was consistent over four harvests (i.e., 147 days, or approximately five months).

Calcium deficiency was not evident until the fourth harvest, and there was no deficiency of Mg., or of minor elements (Cu. Zn. Mn. or Fe.).

In order to obtain some measure of these naturally occurring deficiencies, the data from this experiment were re-analysed, and mean yields were then expressed as a percentage of that obtained with the full fertilizer treatment, (N.P.K.Ca.). Those data were then plotted as a graph showing *relative yields* in the absence of individual nutrients. In order to obtain some measure of reliability, the data from a number of replicates (i.e., corresponding values for all treatments that had no effect on yield) were separately computed. *Mean relative yields*, and standard deviations were then calculated from these individual values. These data for each of the four harvests are shown diagrammatically in Fig 3.

(a) **No Phosphorus.**—In absence of P., mean relative yields did not exceed a value of 47 $\pm$ 5 per cent. and except for a slight drop in the fourth harvest there was no significant difference between mean relative yields for successive harvests.

The data therefore show that without some application of phosphorus, no amount of fertilizer would give yields exceeding 40 per cent. of the potential level of production on this soil.

(b) **No Nitrogen.**—Nitrogen was at all times acutely deficient, and mean relative yields did not exceed a value of 29 $\pm$ 2·9 per cent. in the first harvest. In the second, third and fourth harvests they did not exceed 17 per cent., and there were no significant differences between harvests.

(c) **No Potassium.**—In absence of potassium, mean relative yields decreased steadily from an initial value of 95 $\pm$ 6·8 per cent. in the first harvest, to 4 $\pm$ 2·4 per cent. in the fourth harvest. The data suggest that there were no reserves of normally unavailable K. ; or, at least, no evidence of any conversion to an available form.

(d) **No Calcium.**—There was no evidence of any deficiency of calcium, except in the fourth harvest, when the mean relative yield dropped to 83 $\pm$ 5·5 per cent. In the first harvest the addition of Ca. caused some depression in yield (i.e., mean relative yield exceeding 100 per cent. :—see C.R.I., Bulletin 13), and that effect persisted in reduced degree through the second harvest. In the third harvest there was no effect from Ca.

The data therefore suggest that plants growing on this soil would not suffer from any initial deficiency of calcium, and that any application of lime should be withheld, pending some further experiments with similar soil that has been under crops, or pasture, for one or two years.

## B.—Experiment 2

(i) **Objective.**—To measure the effect of sulphur on two species growing on Ambakelle Forest soil.

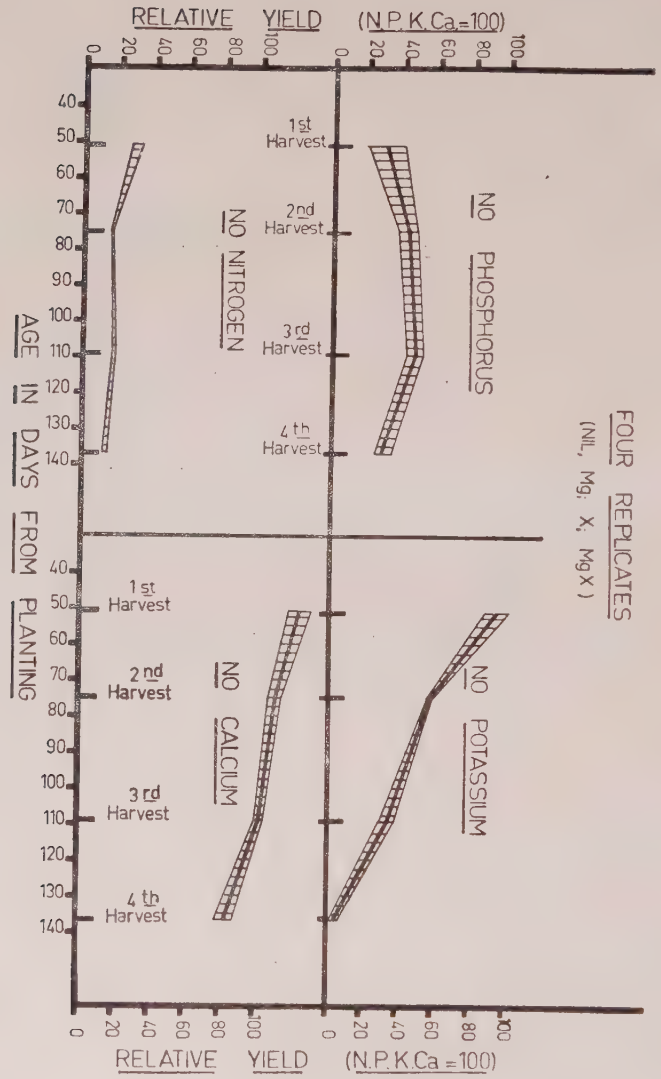


Fig. 3

*Experiment 1. Diagram showing the trend of mean relative yields (± Standard divitions) in successive harvests of* Paspalum commersonii

(ii) **Design and Procedure.**—This was a simple comparison of two treatments 'nil' and 'sulphur' using two species (*Paspalum commersonii* and *Phaseolus lathyroides*). There were ten formulations comprising five mixtures containing sulphur (i.e. $(NH_4)_2SO_4$; $MgSO_4$; $CaSO_4$; $H_2SO_2$ and $S_4$) and five with no sulphur (i.e. $NH_4NO_3$; $MgC_1$; $CaCO_3$; HCl and nil). All formulations contained the same amounts of N.Mg. and Ca., and all pots were given a basal dressing of K. (5 cwt./acre KCl) and P. (3 cwt./acre $NaH_2PO_2H_2O$). The basic treatment was $S_4$ (0·175 gms./pot ≡ 123 lb./acre of S.). The *Phaseolus* was planted on 1st June, and the *Paspalum* on 12th June, 1957. Both species were harvested on 24th July, 1957.

(iii) **Results.**—Individual yields are recorded in Table III. Sulphur did not improve the yield of either species.

TABLE III. *Experiment 2. showing individual and mean yields for two species*

| *Species* | *Treatment* | $(NH_4)_2SO_4$ $NH_4NO_3$ | $MgSO_4$ $MgCl_2$ | $CaSO_4$ $CaCO_3$ | $H_2SO_4$ $HCl$ | $S_4$ $Nil$ | *MEAN* |
|---|---|---|---|---|---|---|---|
| Paspalum | nil | 2·66 | 1·60 | 3·12 | 1·84 | 2·07 | 2·26 |
| | S | 1·62 | 1·68 | 1·71 | 1·91 | 2·18 | 1·82 |
| Phaseolus | nil | 1·14 | 1·41 | 1·32 | 1·08 | 1·20 | 1·23 |
| | S | 1·57 | 0·93 | 0·95 | 0·91 | 1·54 | 1·18 |
| Mean | nil | 1·90 | 1·50 | 2·22 | 1·46 | 1·63 | 1·74 |
| | S | 1·59 | 1·30 | 1·33 | 1·41 | 1·86 | 1·50 |

## C.—Experiment 3

(i) **Objective.**—To measure any effect from increasing dosage of boron, and of calcium on the yield of two species growing on Ambakelle Forest soil.

(ii) **Design and Procedure.**—This was a 4 × 3 × 2 factorial experiment using two species (*Phaseolus lathyroides* and *Medicago sativa*). All pots were given a basal dressing of N., P., K., Mg., Fe., Cu., Zn., Mn., and Mo. Nitrogen was applied as $NH_4NO_3$ (3 cwt./acre); potassium as $K_2SO_4$ (4½ cwt./acre): all other nutrients were applied in forms and doess enumerated in Table 1. There were three levels of calcium :—0, 10 and 20 cwt./acre $CaCO_3$; and four of boron :—0, 3, 6 and 9 lb./acre $Na_2B_4O_710H_2O$.

For this experiment, and in order to avoid boron contamination (i.e., from 'pyrex' glassware) all water was finally distilled in chromium plated apparatus.

Both species were planted on 4th June, 1957. The *Phaseolus* was harvested twice, on 15th July and 1st August, 1957. The *Medicago* was harvested once on 1st August, 1957, but on 16th July, the number of plants per pot—originally two—was reduced to one, and plants removed (designated 'thinnings') were weighed to give some additional data.

(ii) *Results*—Individual yields are recorded in Table IV.

TABLE IV. *Experiment 3 showing individual yields and level of significance for all treatments affecting the yield of two species*

| *Species* | *Harvest* | *Treatment* | *Nil* | $B_3$ | $B_6$ | $B_9$ | *Effective Treatment and Level of Significance* |
|---|---|---|---|---|---|---|---|
| MEDICAGO | Thinnings<br>Age 42<br>Days | $Ca_0$<br>$Ca_5$<br>$Ca_{10}$ | 0·25<br>0·27<br>0·22 | 0·24<br>0·21<br>0·22 | 0·16<br>0·18<br>0·12 | 0·10<br>0·17<br>0·12 | Ca. (5·0)<br>Species (0·1)<br>Harv. × Spec. (0·1) |
| | (1)<br>Age 58<br>Days | $Ca_0$<br>$Ca_5$<br>$Ca_{10}$ | 0·89<br>0·70<br>1·15 | 1·22<br>0·97<br>0·60 | 0·59<br>0·42<br>0·68 | 0·38<br>0·32<br>0·60 | |
| PHASEOLUS | (1)<br>Age 41<br>Days | $Ca_0$<br>$Ca_5$<br>$Ca_{10}$ | 2·68<br>1·85<br>1·39 | 2·07<br>1·73<br>1·82 | 2·02<br>1·58<br>1·94 | 2·00<br>1·74<br>1·92 | |
| | (2)<br>Age 58<br>Days | $Ca_0$<br>$Ca_5$<br>$Ca_{10}$ | 1·15<br>1·08<br>0·77 | 1·40<br>0·99<br>1·17 | 1·68<br>0·69<br>1·13 | 1·68<br>1·15<br>1·57 | |
| | | TOTAL | 12·40 | 12·64 | 11·19 | 11·75 | |

Boron had no significant effect on the yield of either species. Calcium was responsible for some depression in yield (mean values of — 24 and — 16 per cent. for $Ca_5$ and $Ca_{10}$ respectively).

## 3. SUMMARY AND CONCLUSIONS

2. The date from three experiments have shown that plants growing on Ambakelle Forest soil would suffer from an acute deficiency of N. P. and K.

2. In the early stages of growth there was no apparent deficiency of calcium, and plants of *Paspalum commersonii* growing on 2,000 gms. of soil yielded an equivalent of 7·8 tons (dry weight) per acre, in 104 days. In a later harvest (i.e., after 137 days) there was some improvement :—(17 per cent. increment in yield) from an original dressing of 10 cwt./acre $CaCO_3$.

3. There was no evidence of any deficiency of magnesium, or sulphur, or of minor elements :—copper, zinc, manganese, iron or boron, and no visual symptoms of molybdenum deficiency were observed.

4. Deficiencies of N. P., and K. were acute and omission of any one of those three nutrients from the complete fertilizer caused a very great reduction in yield.

In absence of phosphorus, yields were reduced by 60 per cent.
Omission of nitrogen caused an 85 per cent. reduction in yield.
With no potassium, yields declined steadily from an initial value of 95 per cent. to a final value of 2.5 per cent.

5. Correct dosages—i.e., the amounts of individual nutrients which are necessary for satisfactory plant growth—have not been determined, but in these experiments very large doses (6 cwt./acre $NaH_2PO_4.2H_2O$ ; 9 cwt./acre $K_2SO_4$ ; and 17·5 cwt./acre $(NH_4)_2SO_4$ were used in the complete fertilizer, with no adverse effect.

6. The data from these experiments provide clear evidence that a ' virigin ' forest soil in Ceylon can be relatively infertile (see Plate I) ; and that forest growth does not necessarily build, or restore, a high level of soil fertility.

7. It may be a point of some practical importance that with adequate supply of available P, K, Ca, and water, legumes (*Phaseolus lathyroides* and *Medicago sativa*) grew very well in this soil.

## 4. ACKNOWLEDGMENT

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[PLATE I]

*Plants of* Paspalum Commersonii *grown on forest soil from Ambakelle with and without the addition of plant nutrients* (N., P., K., Ca). *Photo taken one week before third harvest of Experiment 1.*

# IMPROVEMENT OF HIGHLAND CROPS IN THE DRY ZONE *

## Part I—Cereals and Millets

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### INTRODUCTION

THE extent of the unirrigable acreage in the Dry Zone of Ceylon has been estimated at 2-2½ million acres. Broadly this land may be classified into two categories, viz., the unrrigable lowlands and the unirrigable highlands—each class comprising approximately half the total unirrigable extent. Experience gained at the Dry Zone Research Station, Maha Illuppallama, has distinctly emphasized the individuality of these two natural land classes. While the unirrigable lowlands are natural pasture lands physically unsuited for arable cropping except for rain-fed paddy, the unirrigable highlands on the other hand have been traditionally *chenaed* under a wide range of cereal, pulse, and oilseed crops.

With the development of more productive systems of agriculture, the need has arisen for improved varieties of crops with a high yield potential and capable of responding to more advanced agricultural practices. Equally important are the quality of the crops and their resistance to natural hazards of the environments such as drought, pests and diseases. The programme of work at Maha Illuppallama seeks to meet this demand for improved varieties. The impact of this programme on the agricultural productivity of the approximately one million acres of unirrigable highland in the dry zone and indirectly in the advance towards self sufficiency in food and higher standards of living can scarcely be over-emphasized.

Recent findings of soil studies at Maha Illuppallama have emphasized the importance of securing as wide a range of crops for the dry zone since it is observed that even within the unirrigable highlands, widely differing soil types occur within short distances. Since these different

** This article is the fourth in a series of contributions from the Dry Zone Research Station, Maha Illuppallama, Ceylon.*

land classes are suited to different cereal, pulse, oilseed and miscellaneous crops, depending largely on their drainage tolerance and soil fertility demands, a wide range of crops is an essential pre-requisite to the development of suitable systems of rotational cropping on all the soil types comprising the unirrigable highlands. An important aspect of the crop improvement work in recent years has therefore been the extensive introduction and testing out under dry zone conditions of a very wide range of cereal, pulse and oilseed crops from similar agroclimatic zones of the world.

The crop improvement programme at Maha Illuppallama thus has two prime objectives :—

1. The search for the most promising crops for the dry zone, and
2. Breeding work directed towards improvement of yield and quality within each crop.

The present article reviews the recent progress made in these directions in respect of cereal and millet crops. The improvement in pulses, oilseed and other crops for the dry zone will be presented in a subsequent publication.

## MAIZE

Maize constitutes the most important cereal crop of the dry zone chenas, next to kurrakkan (*E. coracana*). Almost all the local maizes are flint varieties. The prevalent practice of selecting seed maize for the following season within the small population of maize in each individual chena has conceivably led to steady in-breeding within the local maize varieties, particularly where a single variety is grown in a chena and the chenas are far apart. On the other hand where different varieties of maize have been grown in adjacent chenas, natural hybridisation over the years has probably obliterated all traces of the original varieties. Both conditions are known to exist locally and the indigenous maize varieties may therefore be expected to be either highly mixed or highly in-bred.

Maize is very well suited to the dry zone environment. The average rainfall and its distribution in a normal season are almost ideally suited to the growth of a three and a half month maize crop. The crop has displayed considerable adaptability to varying seasonal conditions, producing almost normal yields in both drier and wetter years. The results of recent trials at Maha Illuppallama have also confirmed the general experience in other countries, that maize responds strikingly to optimum soil management and fertilizer practices. Breeding for maximum yield and for resistance to environmental hazards has been the general objective.

The first step in such a programme is the introduction and testing of as wide and representative a range of local and foreign varieties so as to screen out the best adapted varieties on which detailed studies into their genetic relationships may be undertaken. The programme at Maha Illuppallama has so far been largely concerned with the preliminary phase.

From *maha* 1955/56 when the maize breeding programme was initiated at Maha Illuppallama until *maha* 1957/58, well over 200 varieties of maize have been introduced and tested for their suitability to the dry zone. Nearly 50 varieties collected from the villages of the North-Central Province were also included in these studies. The introductions were made mainly from the U. S. A. and Australia where large collections of maize have been established and from over 16 tropical countries in South America, Africa and South-East Asia. As would be expected the varieties exhibited wide diversity of performance under local conditions, ranging from some poorly adapted types from higher latitudes to a large group of well-adapted varieties. The preponderance within this group of varieties introduced ; particularly from similar agroclimatic regions, over local varieties would appear to indicate a considerable degree of in-breeding within the local varieties, or a paucity of favourable genes in the genotype of the indigenous maizes.

If the correct explanation for the relatively poor performance of the local maizes is the occurrence of a high degree of in-breeding and homozygosity within the local types, the breeding of adapted hybrids involving genetically distinct in-bred lines derived from both local and foreign adapted varieties offers considerable promise. Inter varietal hybrids between local varieties, or local and foreign varieties, of genetically diverse character would offer considerable promise as an interim measure until double hybrids based on in-bred lines have been evolved. On the other hand, if the local varieties owe their poor performance to inherent deficiencies in a heterozygous genotype, i.e., a deficiency of favourable genes, it is apparent that high yielding hybrids for the dry zone would have to be evolved solely from inbred lines derived from adapted foreign varieties, without any participation of local maize varieties. Possibilities for interim improvement of maize yields would be in the use of the best foreign varieties and the upgrading of the local maizes by topcrossing with the most superior and genetically distinct introduced varieties. The actual cause of the poor vigour and productivity of the local maizes thus constitutes a problem fundamental to the planning of a programme of maize improvement in the dry zone.

On the other hand there was visual evidence of potash deficiency, and plants of *Paspalum commersonii* from Ko pots contained as little as 0.87 per cent. $K_2O$. Since our basic technique precluded any possibility of leaching, some form of K-fixation would appear to be the only logical explanation of these low yields, and the death of plants.

The soil used for these experiments was collected in the field and air-dried, for convenience of storage in large wooden bins. It was then transferred to pots and raised to 85 per cent. field capacity with distilled water. Initially there was no evidence of potash deficiency, but in course of some 18-20 weeks acute symptoms were recorded. This suggested that air-drying and disturbance of the soil may have caused some release of normally unavailable K, and that repeated drying and aeration of the soil in Ko pots might have the same effect again.

Accordingly a number of Ko pots from experiments wherein the majority of plants had died, were emptied and the soils aerated and air-dried for periods of two weeks. Those experiments have not been completed, but relative yields of 100 and 80 for K + and Ko pots have been recorded in the first harvest.

At this juncture, the amount of K-fixation could not be assessed, and no opinion can be advanced regarding the mechanism of fixation.

In all three of these experiments and during the third harvest, the majority of plants made relatively slow growth and they showed a characteristic discoloration and necrosis which could not be related to presence or absence of any nutrient.

In Experiment 1, and on visual symptoms, this was attributed to a deficiency of calcium, but in Experiment 2, the same symptoms appeared irrespective of the presence or absence of Ca, and they were again apparent in Experiment 3.

In Experiment 3, all plants of *Paspalum,* irrespective of treatment, were rated according to the intensity of these symptoms, and those ratings compared with recorded *p*H for individual pots. There was a significant but false correlation (—0.5399) (co-efficient for error not significant) and it appeared that both were related to some other factor. Both ratings and *p*H were then compared with the cumulative yields for all major treatments. The correlations between 'yield' and 'symptoms' (+0.8790), and between 'yield' and '*p*H' (—0.7108) were both significant. However by using partial correlations it was shown that the correlation between 'symptoms' and 'yield' with constant *p*H was highly significant (+0.8363) ; and *p*H, with constant yield, was not significant (—0.2505).

1956/57 outyielded the standard variety in this yield trial. Of the 30 varieties retained for final testing in a preliminary yield trial during this season, only four, viz., the introduced varieties *Nyoka Flat White G. H.* 188 and *Synthetic* 521, and the local variety *Negampaha* 2 gave indications of a high yield potential, while four other varieties *Oklahoma* 301, *G. H.* 293, *Mannaram* 2 and *Negampaha* 8 also compared very favourably with *Yellow Maize*. The rest of the varieties have been excluded from further yield trials, which will be restricted to the more promising of the newer introductions.

As a result of the above work on the testing and evaluation of maize varieties, over 150 varieties of local and foreign maize have already been rigorously screened for their adaptability to the environmental conditions of the dry zone. The number of adapted varieties to be used in the further improvement of the crop by in-breeding and the development of high yielding hybrids has been reduced to a small and manageable number. Exploratory intervarietal hybridisations to assess hybrid vigour in crosses amongst these varieties, and morphological studies directed at classifying these varieties into races and thus estimating the genetic diversity amongst them, are already in progress. These studies will provide the necessary basic information for the planning of a sound programme for the maximum and most efficient utilisation of hybrid vigour and the development of high yielding hybrids for the Dry Zone of Ceylon.

## SORGHUM

Sorghum appears to have been introduced into Ceylon only around 1930 but the encouraging performance of the crop in the dry zone and its unrivalled potential as a substitute cereal for rice merited for the crop a priority in importance equal to that accorded to maize. Sorghum is distinctly more drought resistant than maize and is particularly suited to the lower rainfall areas of the dry zone which are too dry for maize. The crop is also adapted to a wider range of rainfall and soil conditions than maize. Thus, although the best yields of sorghum are produced in relatively drier years, there is very little depression in yields in wetter years particularly on well drained soils. Yields have, on the average, been almost as high as those of open-pollinated maize varieties.

Apart from its desirable characteristics of high yield and resistance against environmental fluctuations, nutritional and food technological investigations have stressed the potential of sorghum as the best available substitute for rice among the highland cereals of the dry zone. The analyses conducted by Joachim and Panditteseker a (1938) on the

nutritional value of cereals and millets in Ceylon revealed that although the protein and carbohydrate contents of sorghum, maize and unpolished rice are very similar, the mineral content of sorghum grain is nearly thrice as high whilst its calorific value is the highest amongst the common cereals. The grain is far more digestible than that of maize while the flour is eminently suited for use in food preparations in the manner of rice flour. The small grain size of several lax panicled varieties has also offered attractive possibilities for the use of sorghum grain in the same fashion as cooked rice, provided certain technological problems are overcome.

While the high degree of drought resistance, considerable range of adaptability and its nutritional attributes have endowed sorghum with its high potential and possibilities as an ideal rice substitute, experience has revealed the importance of several other characteristics as essential pre-requisites in an ideal grain sorghum for the dry zone of Ceylon. Dwarfness of habit, an open lax panicle, white or pearly seeded grain, and corneous endosperm constitute the most important of these essential characteristics. The importance and desirability of the dwarf habit and laxity of the panicle are closely related to the heavy incidence of bird damage in this crop—a factor which has proved to be the most formidable obstacle impeding the popularisation and expansion of sorghum. The degree of devastation of dwarf varieties is much lower than in the taller varieties owing to the easier and more effective control of bird attack. Open lax panicles also exhibit a lesser degree of bird damage since the activities of the birds are considerably hampered in such panicles. A further advantage of laxity in the panicle is associated with the frequent occurrence of unseasonal rains during maturation of the grain since the occurrence of moulds and of germination within the panicles is retarded.

The desirability of the grain characteristics—white or pearly seededness and corneous endosperm—is associated with the role of grain sorghums as a substitute cereal for rice. Palatability of sorghum grain is closely governed by the absence of an astringent principle in the grain, and white or pearly seeded varieties exhibit almost complete freedom from this undesirable characteristic. Varieties with pigmented grain—particularly the darker pigments—are characterised by the presence of astringency. The character, corneous endosperm, is correlated with good milling quality, slower development of rancidity in storage and a distinctly lower degree of susceptibility to insect pests. Varieties possessing floury endosperm are undesirable in all these respects.

None of the earliest introductions made around 1930 possessed all the desirable characteristics of the ideal grain sorghum. In view of

the importance of sorghum as a dry zone cereal, an elaborate programme of introduction of foreign varieties was initiated in 1952. Nearly 150 varieties have since been introduced, mainly from India, S. Rhodesia, the Sudan, the Belgian Congo, Australia and the U. S. A. Although most of the introduced varieties were grain sorghums, none of the varieties within the wide range combined all the characteristics associated with the ideal grain sorghum. Two distinct groups were, however, clearly distinguishable, viz., the medium tall and tall open lax-panicled varieties characterized by small white or pearly corneous grain, and the dwarf or medium-height varieties possessing a stiff, compact or semi-compact panicle with large and generally floury grain. The lax panicle varieties possess almost all the desirable attributes of the ideal grain sorghum except the vital dwarf habit characteristic of some of the stiff panicle varieties. Substitution of the dwarf character, in the character complex of the lax panicle varieties, would be expected to produce the ideal variety and the breeding programme with sorghum is accordingly directed towards the achievement of this recombinant type.

Observational studies and subsequent yield trials carried out on the entire range of grain sorghums over the past five years have already defined the highest yielding varieties in the crop under dry zone conditions. The results have been consistent despite considerable fluctuations in the rainfall from season to season. The highest yielding varieties comprise both lax panicled and stiff panicled types, viz., *C.O* 2, *C.O.* 3, *Sanpyaung A. S.* 475, I.P.I—*Jowar* 3, *Fulgar White, Tambagala* and *Combine Black Kaffir*. The varieties *C.O.* 2, *C.O.* 3 and *Sanpyaung* are tall open lax panicled types whilst *A.S.* 475 and *I.P.I.—Jowar* 3 are also lax panicled varieties, but characterised by medium heights. Among the stiff semi-compact panicle types *Fulgar White, Tambagala* and *Combine Black Kaffir,* the latter alone is characterised by dwarf height. The breeding programme seeks to transfer by the back-cross method the genes for dwarfness present in *Combine Black Kaffir* into the genetic background of the otherwise desirable high yielding lax panicled varieties.

The important sub characters governing the differences in gross morphological structure of the panicle in sorghum are the length, degree of stiffness and the disposition of the grains on the panicle branches. Semi compact stiff panicle types like Tambagala and Combine Black Kaffir are characterised by very short, highly condensed, stiff panicle branches, bearing grain along almost their entire length. The open lax panicles varieties like *C.O.* 2, *C.O.* 3, *Sanpyaung* and *A.S.* 475 are on the other hand characterised by their very long, uncondensed, slender, flexible branches. The grains are borne only on the

distal halves of the primary and secondary branches, causing top-heaviness and consequent dropping of the laterals. The latter group of varieties also possesses the desirable grain characteristics of small size and corneous endosperm in contrast to the large grain and more floury endosperm of the stiff panicled type. In the backcross programme for developing the ideal grain sorghum, therefore, five genetic correlations are of importance, viz., between plant height on one hand and length and texture of the panicle branches, and grain disposition, size and endosperm character on the other. Studies to determine these values have been initiated along with the programme of backcrosses involving *Combine Black Kaffir* as the non-recurrent parent and several lax panicled varieties *C.O.* 2, *C.O.* 3, *Sanpyaung, A.S.* 475 and *I.P.I. Jowar* 3 as recurrent parents.

Besides its importance as a grain crop, sorghum is also a potential forage crop for the dry zone. Forage varieties of sorghum constitute a distinctive group distinguishable from the true grain sorghums. They are characterised by tall, sweet, succulent stems carrying a greater density of foliage. The grain is generally pigmented, astringent and almost completely enclosed by persistent well developed glumes in contrast to the unpigmented palatable and exposed grain of the grain sorghums.

Of the large number of introduced varieties of forage sorghum tested at Maha Illuppallama, the variety *Sweet Honey* has consistently proved to be forage sorghum 'par excellence' for the dry zone. Yields of green forage have averagd as high as 15 tons per acre without fertilizers. These figures compare very favourably with the annual yields of 15—17 tons of green forage produced by *Brachiaria* pastures under fertilized conditions. The total yield from forage sorghums on fertilized soils may be expected to be considerably higher since it is general experience that the crop responds markedly, particularly to nitrogenous fertilizer.

## MINOR MILLETS

Apart from maize and sorghum, several minor millets are of considerable importance as cereal grain crops in the dry zone. Finger Millet, Kurakkan or Ragi (*Eleusine coracana*) is the most widely grown cereal crop in the Maha chenas. It is particularly suited to the poorer-drained lower slopes which are too moist for maize or sorghum. Another minor millet, Meneri (*Panicum miliaceum*), constitutes the commonest cereal component of the *Yala* chenas of the dry zone. The extremely short duration of this crop endows it with the capacity to

mature and produce reliable yields of grain during this season. Bulrush millet or Kambu (*Pennisetum typhoideum*) is a more recent introduction offering considerable promise as a yala cereal for the dry zone.

The minor millets are in general better balanced foods than rice, sorghum or maize, by virtue of their higher protein, fat and mineral contents. The protein contents of tanahal (*Setaria italica*), Meneri and Kambu are over 50 per cent greater than that of rice, sorghum or maize. Seed storage also presents a less acute problem in the minor millets since damage from insect pests is not as severe as in sorghum or maize. Meneri is almost immune from attack, while Kurakkan, tanahal and Kambu are damaged only to a very limited extent.

Finger Millet, Kurakkan (*Eleusine coracana*) is the only minor millet of importance in the dry zone during the *maha* season. The crop is moisture loving and well adapted to the relatively high rainfall conditions that commonly prevail during this season. Tanahal and Kambu are highly drought resistant crops suited to regions of low rainfall and their relatively poor performance in the dry zone during *maha* is presumably due to excessive moisture conditions. During *maha* 1956-57 a yield trial of 12 kurakkan and tanahal varieties was set down. The results clearly demonstrated the superiority of kurakkan varieties over tanahal varieties—the increase in yield of the former being as high as nearly 40 per cent. The kurakkan varieties *Ragi* 958 and *Ragi* M-1 introduced from Madras significantly outyielded the current Departmental selection E. 43 by over 18 per cent. The trial is being continued to confirm the superiority of these varieties.

In view of the importance of kurakkan as a highland cereal in the dry zone, work on the improvement of the crop has been intensified. Besides the primary objective of increased yields, the breeding programme with kurakkan aims at improving qualitative characteristics of the crop—particularly resistance to lodging, even maturity and a loose panicle. Most of the local varieties and introduced varieties exhibit heavy lodging and uneven maturity, characteristics leading to considerable loss of seed and increased harvesting costs. A non-lodging, uniform maturing variety possessing a loose panicle structure is the objective of the kurakkan breeding programme in progress at Maha Illuppallama. The possession of a loose panicle constitutes an important characteristic owing to the frequent recurrence of unseasonable showers during maturation. The introduced higher yielding varieties *Ragi* 958 and *Ragi* M-1 possess this panicle characteristic, which is lacking in most of the indigenous varieties.

Local varieties appear to be relatively poor yielders compared to the improved Indian varieties, while genes for lodging resistance and uniform maturity are also apparently lacking in the indigenous material. A programme of introduction of varieties, particularly from India and Africa where the crop occupies a position of importance, is now in progress. Already over 10 new varieties are under observation. The identification of high yield potential, lodging resistance and uniform maturity within the wide range of local and introduced varieties now being collected, and the determination of heritability values of these and other important qualitative characteristics constitute the immediate objectives of the programme of work with this crop.

Meneri (*Panicum miliaceum*) is the most important, if not the only cereal crop grown in the dry zone *chenas* during the *yala* season. Like gingelly and perhaps green gram, it is one of the very few short-duration crops which can be sown with the first *yala* rains and mature before the soil dries out by the middle of June. Yields are very low but, nevertheless, reliable unlike in sorghum or maize which more often than not, fails completely during this season. Work on the improvement of the crop has been initiated with the collection of a representative range of varieties both locally and from abroad. An earlier-maturing higher-yielding variety is the objective of the breeding programme with this very nutritious *yala* cereal.

The possibility of growing crops of Bulrush or Pearl Millet (*Pennisetum typhoideum*) and photoperiod-insensitive, short-duration varieties of sorghum and maize during the *yala* season is presently under investigation. Considerably higher yields of grain may be expected if a suitable variety in these crops can replace Meneri during the short *yala season.*

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# LAND CLASSIFICATION IN CEYLON WITH REFERENCE TO BASIC CONDITIONS OF SOIL AND WATER CONSERVATION *

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LAND classification for purposes of soil and water conservation is very complex in view of the fact that it goes beyond a simple objective classification of physical factors such as geology, soil, topography, steepness of slope, climate, vegetation cover, &c., but includes such human factors as patterns of agriculture, sociology and economics. For effective conservation it is necessary to carry out surveys of all these factors in great detail and in very small units such as individual farms or estates, the final result being a Land Use or Land Capability Map.

The contribution we as geologists can make to such a classification is to provide as far as possible the basic physical factors of environment with which we are familiar in the course of our normal routine work. The significance of land use or rather land misuse in causing deterioration and loss of soil and water has been brought out very strikingly in a recent study of major land slip areas of the Island. However, this aspect of the land is a specialised study requiring special techniques of investigation and is a function of the Soil Conservationist. The classification which is proposed is based mainly on the physical environment and leaves out this important aspect of the land.

The processes of normal geological erosion are well known and will not be considered now. These are natural processes which take considerable ages of time, but can be accelerated by human agencies to cause sudden loss of soil and water. The basic facts which we are concerned with are soil and water in the land. It is generally accepted that almost all water on the surface of the land and in the ground beneath is derived from precipitation in the form of rain, snow and ice, and almost all the soil is derived from the parent rock material under the action of the various pedogenic agents.

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In Ceylon precipitation is essentially in the form of rainfall which varies from 50 in. per annum in the north-west and south-east parts of the Island of the lowland zone to over 200 in. in the south-western slopes and the hill country. The central highland zone is about 100 in. and the remaining portion of the lowland zone 50 in. to 75 in. The mean rainfall of the Island is about 80 in. per annum.

Crystalline rocks of pre-Cambrian age occupy nine-tenths of the Island's surface. These comprise in the main a series of Gneisses—the Vijayan Gneisses and the Khondalite Group of Rocks which consists of intensely metamorphosed sediments of pre-Cambrian age and show a great variety of lithological types. Associated with the Gneisses and the Khondalite rocks are the Charnockite series of hypersthene-bearing granties and a less extensive pink Tonigala granite of the north-western part of the Island and coarse-grained, pegmatitic granites younger in age.

These rocks have been folded into a complex northward pitching synclinorial axis striking in a north-north-west to a south-south-east direction through most of its length, and has had a very marked effect on the erosion pattern of the Island and its topography, ridge and valley coinciding with the structural trends.

With the exception of a fragmentary representative about a square mile in extent of Upper Gondwana Age occurring in the Tabbowa area, there is a lack of younger formations until Miocene times. Miocene rocks consisting of fossiliferous limestone occupy an area of 800 square miles and occur in two widely separated areas. The Kudremalai-Jaffna series is in the north-west of the Island and a very small deposit occurs in the extreme south-east, in the Yala area.

The Pleistocene and Recent deposits are from the point of view of soil and water conservation the most important formations of the Island. Their distribution is shown in the soil map which is a simplified sketch of Dr. Joachim's Provisional Soil Map of the Island (Joachim 1945). The crystalline rocks of the south-west are capped by varying thickness of laterite derived from the decomposition of the underlying granites and gneisses, under the prevailing conditions of temperature and precipitation. The alteration of the crystalline rocks in the dry zones of the south-east and north-east has resulted in the formation of a lateritic earth.

Intermediate in age between the Pleistocene laterite and Sub-Recent and Recent deposits of river alluvium, littoral sandstone and beach sands, there occurs in well defined but inconstant horizon a well rounded gravel mixed with red earth—the "Post-pliocene gravels." These occur in the north-western and northern parts of the Island in a few isolated and widely separated patches, in the area shown in the

Geological sketch-map as a continuous formation. The thickness varies from 8-10 feet though some 40-50 feet thickness has been known to occur in mounds to the north of Anuradhapura.

The intimate relationship between land and water is clearly brought out in nature's water cycle. The rain falling on the land is disposed of as direct run-off, evaporation and transpiration from vegetation, evaporation from free water surfaces and soil and seepage into the ground to augment the water table.

The proportion of the rainfall available for direct run-off is the residue after the demands of percolation, evaporation from the soil, surfaces of water and vegetation (including transpiration and evaporation of rain water intercepted by foliage) have been satisfied.

The mean annual rainfall for the Island is about 80 inches or about 107 million acre-feet; Abraham (1946) estimated the total run-off from the Island as being 27.5 million acre-feet or about 25 per cent. of the mean annual rainfall.

The Administrative Report of the Director of Irrigation for 1952 contains data on the annual river flow measured at over 50 complete gauging stations in the main catchment areas of the Island, over a period varying from 6 to 28 years.

Ten gauging stations in the "Wet Zone" had an annual run-off of 71 per cent. to 84 per cent. of the rainfall, with one station over 100 per cent.

Ten stations located in the Humid Zone had a run-off from 47 per cent. to 67 per cent.

Out of twenty-seven stations located in the Dry Zone eighteen had a run-off from 25 per cent. to 47 per cent. and nine had from 12 per cent. to 22 per cent.

There is very little information available on the analysis of river flow into its main components, surface run-off and ground water run-off. The magnitude of these components will depend on the nature of the catchment basins, particularly the depth, permeability and storage capacity of the soil and underlying rock and the character and distribution of the rainfall.

The discharge curve of some of the larger rivers of the Island can be seen to consist of several irregular peaks separated by short stretches of uniform base flow. This is to be expected from the geological make-up of the Island —the lack of rock formations capable of storing large quantities of ground water.

Normal monsoonal rainfall is more or less evenly distributed in most parts of the Island. Thunderstorm and cyclonic rains are generally



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characteristic of the inter-monsoon periods. Thunderstorm rain fortunately occurs with great intensity in the dry lowlands. For instance, some maximum intensities that have been recorded for the Island are—

| | | |
|---|---|---|
| Mullaitivu | .. | 31.18 inches in 24 hours |
| Nitre Cave | .. | 24.78 inches in 24 hours |
| Chavakachcheri | .. | 21.17 inches in 24 hours |
| Jaffna | .. | 20.48 inches in 24 hours |
| Colombo | .. | 11.40 inches in 24 hours |

Heavy storms of this nature when they occur in the highland zone can cause severe damage to the land such as the storms of 14th and 15th August, 1947, when rainfalls of 17 to 35 inches in 48 hours were recorded. These storms caused peak discharges of 242-276 cusecs per sq. mile in the Kelani catchment and 390-450 cusecs per sq. mile in the Mahaweli Ganga upland catchment—the largest flood discharges recorded since 1870.

The nature of the rainfall and the relief of the land are thus conducive to a rapid run-off with consequent loss of top soil—this loss of soil and sub-soil mean that underground sources dwindle, as the soil is the most important carrier of water in the Island.

Areas where the precipitation is in excess of evaporativity* the magnitude of the excess will give an index of the effectiveness of precipitation, as the residual available for maintaining stream flow and for percolation to ground water will be greater. On the other hand where the precipitation is less than the evaporativity, the amount available for replenishment is small ; the magnitude of the deficit will give an index of aridity. On this basis the following "*Zones of Effective precipitation*" can be recognized :—

TABLE 1.—*Effective Precipitation Zones*

| *Moisture Zone* | *Annual Rainfall* | *Annual Evaporativity* | *Annual Effective Rainfall* | *Annual Run off/ Rainfall Per Cent* |
|---|---|---|---|---|
| (A) Wet Zone | 100 " to 200 " | 34 " to 65 " | 740 " | 71–84 |
| (B) Humid Zone | 75 " to 100 " | 60 " to 82 " | 0–40 " | 47–67 |
| (C) Dry Zone | 50 " to 75 " | 70 " to 98 " | –40 "–0 " | 25–47 |
| (D) Arid Zone | less than 50 " | greater than 86 " | lessthan–40 " | 12–22<br>0 to 12 |

"*Note* :—*Evaporativity*, or potential evaporation is definied by Meinzer (1923) as being "the rate of evaporation under the existing atmospheric conditions from a free surface of water that is chemically pure and has the temperature of the atmosphere."

Some values of evaporativity calculated for the Island on an empirical formulace are given in Table I.

## LAND CLASSIFICATION

A tentative and broad division of the Island based on a combination of climate, topography, soils and geology is suggested as a basis of classification for soil and water conservation for the Island. Since these factors exert a major control on the mode of occurrence and flow of water in the soil and sub-soil the regions thus defined should possess a broad uniformity of character.

Five major divisions are proposed as follows :—

(1) The Wet Highland Zone,

(2) The Humid Upland Zone,

(3) The Dry Lowland Zone,

(4) The Miocene Limestone Zone of the North,

(5) The Coastal Zone.

**(1) The Wet Highland Zone** includes the zone with effective precipitation greater than 40 and a surface run-off from 70 in. to 160 in. per annum. The general elevation can vary from 3,000 ft. M. S. L. to over 8,000 ft. Geologically this zone is composed of the Khondalite group of rock referred to earlier. They are traversed by a well defined system of joint and fissure planes. The topography has been profoundly effected by the geological structure. The dominant feature of these systems of valleys is the presence of well defined scrap slopes with steepness in certain cases exceeding 80°. There is no continuous water table but there is a vigorous circulation of water in the joint and fissure planes of the rock as evidenced by the numerous springs that issue from them. The discharge from these springs can vary from over quarter of a million to half a million gallons per day.

The soil cover is mainly lithomargic or kaolinitic in character, the clay content being very often over 45-50 per cent. The depth of this soil cover is variable and extends in certain areas to over 100 ft. The presence of this kaolinitic material causes much instability and slumping when it is in a state of over saturation. The conditions which favour this fall broadly into two categories (*a*) conditions inherent in the areas and relate to geological, structural and topographical features over which man has no control, and (*b*) a set of conditions which have been imposed on the area by the activities of man.

The Kotmale and Ginigathena slipped areas are typical of this zone.

**(2) The Humid Upland Zone**—Geologically this zone is similar to the wet highland zone. The essential differences are its lower elevation, less steep topography and smaller effective precipitation. The dominant soil cover is laterite. A typical laterite profile shows



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a transition from partly decomposed gneiss through an intermediate zone of kaolin and angular quartz to typical vesicular and sectile laterite of high porosity and permeability. This is capped by a loose layer of ferruginous nodules immediately under the soil. Thickness of the laterite cover can in general vary from 40-50 feet.

The hard laterite can often support near vertical slopes but the soft laterite has a tendency to cave in when over saturated. There is a considerable oscillation of the water table during the year. The rise of the water table to its upper limit after a few hours of heavy rain is characteristic. Any excess rainfall tends to flow over the saturated ground and causes considerable amount of gully erosion.

**(3) The Dry Lowland Zone**—The rocks in the zone belong to the same types as in the highlands but there is here a more extensive development of the Vijayan Gneisses. As in the Highland Zone there is practically no continuous water table in the crystalline rocks. Numerous springs however issue from the fissures and joints of the quartzites and crystalline limestone and gneisses and yield from 15,000 to 50,000 gallons per day.

The laterite of the humid zone gives place in the dry zone to a friable mixture of quartz sand and ferruginous clay, which in turn gives place to a red and reddish brown earth in the drier parts of the zone. Occasionally a non-lateritic grey loam occurs in certain districts. The colloidal clay content of the dry zone soils is much lower in them than in the laterite of the humid zone, being only about 15-20 per cent. They are nevertheless derived from the same rock type their differences being due to the different climatic conditions governing their formation. As a result of the prevalent aridity in the area most of the rivers are dry during a part of the year and some areas are practically areas of internal drainage. This results in a retention of salts which would normally have been carried to the sea in solution by rivers, and accounts for the hardness of the water and the occurrence of concretionary nodules (Kankar) in layers of two or three feet in the sub-soil in certain localities.

The water from these areas will generally be high in mineral matter and hardness and possess a high degree of alkalinity.

Where the bed rock is irregular, basin shaped depressions of alluvial soil overlying a disintegrated rock provide good aquifers for the storage of ground water.

The Alluvium of the major river systems often store considerable amounts of ground water, that drains to the sea slowly as under flow. This water could be conserved for use.

The relatively low relief and thin soil cover, generally less than 40 to 50 feet thick in this zone, results in very meagre storage of water underground. A continuous water table occurs only for a short period after the rainy season. As the dry season progresses the water-table declines and towards the end of the dry season water is found only in isolated pockets of decomposition in the crystalline rock floor, or in areas where the water-table is artificially maintained by means of a tank or irrigation channel. Natural streams and water courses, except rivers taking their rise in the central hills, are reduced to a trickle or are completely dry during the dry season.

Under the prevailing climatic conditions the soil of the dry zone has a tendency to rapid destruction of the soil organic matter and consequent deterioration of its physical conditions rendering the soil open to vigorous erosion as a result of the torrential rains that fall upon this area. Varying agricultural practices from the earliest times have added to the impoverishment of the soil.

The development of this zone is progressing fast and it is very essential that effective measures should be adopted for conserving the soil and the water contained therein.

This zone also includes the portions of the two areas climatically coming under the " Arid Zone." The processes of erosion are more intense than in the rest of the Dry Zone and have given rise to almost desert conditions where in addition to the erosive action of water we have erosion due to wind. The Desert Tracts of the North-West Arid Zone are well known and have been described by Wayland.

**(4) The Miocene Limestone Zone of the North**—The limestone is best developed in the Jaffna peninsula, which is entirely composed of it. The limestone varies from a somewhat cellular material full of coral to a massive rock in which gastropods are common. It usually weathers into a honey-combed mass. The soil cover is the bright red free-draining " Terra Rossa " from 1 to 8 feet thick. Sand dunes fringe the peninsula, particularly in the south-west, where spites or tomboli link it up with the mainland.

The surface of the land is comparatively flat rising in the north to over 30 feet M. S. L. The permanent level of ground water saturation is at sea level, the body of fresh water occupying a Gyben-Herzberg lens of depth about a 100 feet at the centre of the peninsula, floating on brackish water. There is a considerable amount of fresh water discharging from this lens to the sea in coastal springs.

While the problem of soil erosion is not so acute here, there is a need to conserve supplies of fresh water. This can be achieved by augmenting the amount of percolation into the ground by delaying surface run-off and by building dams to prevent the inroad of sea water into the low-lying lands and contaminating the fresh water table.

**(5) The Coastal Zone** is divisible into 5 well marked sub-divisions based on geological structure and the nature of the accumulated deposits. These are—

(*a*) *The Eastern coast* extending as a continuous belt from Hambantota to Point Pedro with the exception of a small stretch from Trincomalee to Kuchchaveli.

(*b*) *The West coast* belt stretching from Panadura to Puttalam with a maximum inland extension near Chilaw.

These are characterized by cumulative deposits of dune sand, beach bar, sand spit and lagoon deposits. These deposits are characteristic of a stationary or emegent coastline.

(*c*) *The North-west coast belt from Puttalam to Point Pedro*—This part of the coast is backed by Miocene Limestone rocks and gives rise to low cliffs that stretch from Kudremalai to the Jaffna coast.

(*d*) *The South-west coast from Panadura to Hambantota* is a typical drowned valley system cut off from the open sea by sand bars and is characteristic of a submerged coastline. The coastline is concordant and trends in a direction parallel to the structural strike of the hills which approach the sea and terminate in small promontaries and cliffs. This stretch of coast receives the full blast of the South-west monsoon and its form shows that it is being rapidly eroded.

(*e*) *The portion of the North-East coast from Trincomalee to Kuchchaveli*—The North-east coastal tract from Trincomalee to Kuchchaveli is discordant—the rocks striking athwart the coastline. Here too the rock rises steeply from the sea in cliffs like those found north of the Trincomalee harbour. This portion of the coast is actively acted upon by the North-east monsoon.

The coastal lowlands are a tract of country where vertical corasion is at a minimum as the base-level of erosion has about been reached. We are in the flood plain of rivers where lateral corasion and bank erosion with periodical flooding is predominant. These lands are attacked in two fronts from the land as well as from the sea. The full force of wave, wind and tidal currents has to be withstood in

addition to the erosive action of water flowing seawards from the land. The problem of soil conservation here is thus complex and the measures to be adopted should be of a different nature to that in the upland areas.

There is considerable storage of fresh water in the more permeable formations of the coast, floating as lenses or lenticular bodies on top of saline sea water. This delicate balance is possible so long as the fresh water body is able to maintain a head above sea level. This is accomplished by recharge from rainfall and infiltration from streams draining the main land. Excessive pumping from wells or the acceleration of natural drainage into the sea artificially, results in the encroachment of brackish water and gradual depletion of the fresh water stored in these formations.

The storage facilities in the coastal area is variable and the amount of water that can be withdrawn from the ground has to be determined carefully for each area, so as to conserve supplies of fresh water for human use. Artificial recharge of the water table by delaying run-off and increasing infiltration rate by improved soil management are some of the means that can be adopted to increase the storage of fresh water.

In the foregoing an attempt has been made to demarcate very broadly Basic Zones for purposes of soil and water conservation in the Island. This has been done by superimposing the geology, topography, effective rainfall and the soil of the Island.

The major zones so defined, should be capable of subdivision into regions according to detailed topography, depth, texture, and permeability of soils, slope characteristics and vegetation cover. The regions in turn should be capable of further subdivision according to land use and agricultural and farming practice, the farm or estate forming the unit to be used for this stage of the survey. In this manner it will be possible to build up the final survey of soil and water conservation of the land.



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# THE RHINOCEROS BEETLE (Oryctes rhinoceros L) IN CEYLON

## Part I.—Introduction, Distribution and Life History

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### INTRODUCTION

THE IMPORTANCE of the Rhinoceros beetle as a pest of the Coconuts in Ceylon has been realised for many years. It was declared a pest in Ceylon, under the Plant Pest Ordinance No. 6 of 1907. The Ordinance does not, however, appear to have been strictly enforced, and the Rhinoceros beetle continues to be one of the most damaging of coconut pests.

**Taxonomy.** Classification is as follows :—

*Order* Coleoptera : beetles.

*Suborder* Lamellicornia : stag-beetles, passalids, scarabaeids.

*Family* Scarabaeidae : Scarabs, dung beetles, june beetles, etc.

*Subfamily* Dynastinae : Rhinoceros, much, and cane beetles.

*Tribe Oryctini* : true Rhinoceros beetles.

*Genus Oryctes* : palm Rhinoceros beetles.

*Oryctes rhinoceros* (Linnaeus) : coconut Rhinoceros beetle.

**Distribution.** The Rhinoceros beetle was first recorded on coconut palms by Ridley in 1889 in the Strait Settlements. It occurs in India, Burma, Siam, the Malay Peninsula, Indo-China, Hainam, Phillippines and Indonesia as far east as Celebes, Ceram, Amboina (Arrow Leefmans) and Africa.

The Rhinoceros beetle first entered the South Pacific area in 1909, when it was introduced into Samoa with rubber plants from Ceylon (O'Connor, 1953). The beetle has also been introduced into Wallis Island, New Britain, New Ireland, Palau, Tonga, and Fiji. After the war the beetle was found to be established in the Bismark Archipelago, Territory of New Guinea, and also in the Caroline Islands

north of equator. In February, 1952, it was discovered in Vavau and had evidently been there for some considerable time. The Palaus are the only islands in Micronesia where it has been found (Gressitt, 1953).

Of the 42 recorded species of *Oryctes*, only four are present in South East Asia or New Guinea. Fifteen are found in Africa, 14 in Madagascar, two in Mauritius and one each in islands called Reunion, Sao Thome, Comoro Island, Socotra Island, Rodrigues Island and the Canary Islands. *Oryctes rhinoceros* is found from South Asia to the South Pacific.

Of the 25 species which attack palms, 15 attack coconuts. *Oryctes rhinoceros* has 29 host genera, 16 of which are palms.

It can be said that the Rhinoceros beetle is a pest of coconut wherever this palm is grown. In Ceylon, the distribution of the Rhinoceros beetle closely corresponds to the coconut growing areas. Gressist (1953) says that *Oryctes* is rarely found at altitudes higher than 900 metres. Our observations agree with his findings.

**Habitat.** The adult beetles become active about dusk and after dark, but during the day they are normally found either feeding on the crowns of palms or in heaps of decaying organic matter. The eggs are laid in decaying organic matter, such as cattle dung, saw dust, manure heaps, decaying refuse, e.g., coconut husks, stalks and leaves, decaying coconut logs and stumps (See Plate 1).

In the Eastern Province of Ceylon, breeding of beetle takes place mainly in decaying coconut logs. The larvae are present at the edges of the heaps of fibre dust near fibre mills. Oviposition was once observed on a palm where a hole was sealed up with clay, but the larvae that hatched out did not develop. A female beetle was found to have oviposited in a young fallen nut (Plates 2 and 3).

**Alternate Host Plants.** *Oryctes* generally feed on palms. Its first preference is the coconut palm but it can feed on a number of other host palms such as the Palmyra palms (*Borassus flabellifer*), the toddy palm (*Phoenix sylvestris*) and the oil palm (*Elaeis guineensis*). Less important host plants are the nipa palm (*Nipa fruticans*), the nibong palm (*Oncosperma tigillaris*), the talipot palm (*Corypha umberaculifera*), the sago palm (*Metroxylon sagu*) and some other ornamental palms.

The beetle also occurs on sugar cane (*Saccharum officinarum*), pineapple (*Ananas comosus*) and banana (*Musa sp.*).

**Nature of Damage.** Gressitt (1953) reports as follows on the feeding habits of the adult *Oryctes* :

*Plate 1*—A typical site of oviposition in a heap of cow dung and straw. In such heaps all stages of larvae are found. Pupal cocoons also exist 4-5 inches below the soil surface.

*Plate 2*—Female beetle has bored into this fallen immature nut and fed on the tissue.

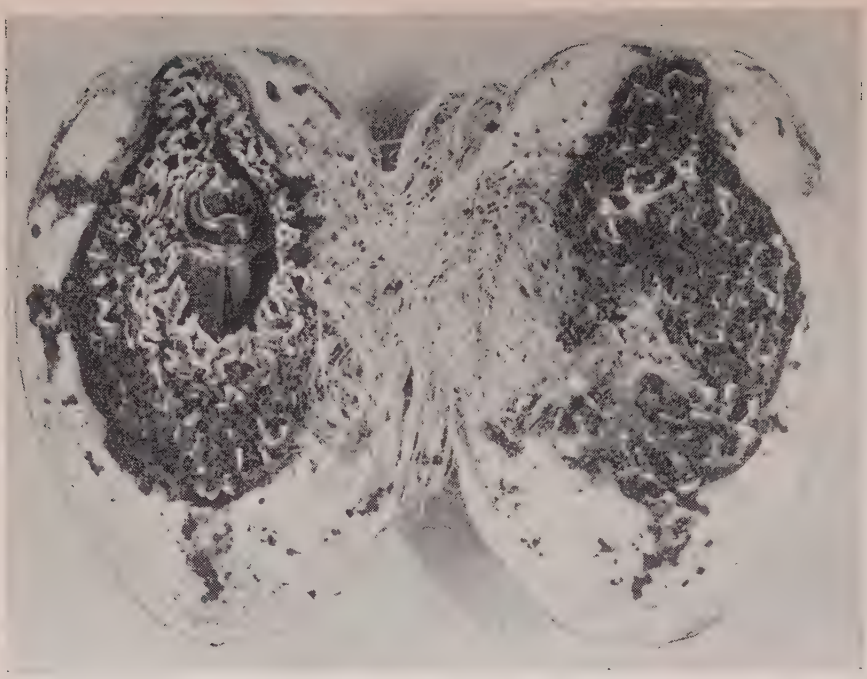

*Plate 3*—The nut depicted in Plate 3 is split open longitudinally to expose the beetle. One egg was found among the frass contained in the cavity.

*Plate 4*—Four-year old palm damaged by the beetle. Note the large symmetrical gaps left in the fronds (giving them a frayed appearance) due to the chewing of the unopened frond.

"The adult beetle flies at night from its place of emergence in a rotten log, stump, trunk or compost heap to the top of a living coconut palm. It then enters the side of an upper or middle frond near the growing point by crawling down the upper surface of the petiole, crowding its way down between that and the one inward from it. It then bores inward to, or near to, the centre of the crown above the growing point and digs it way downward through the white centre consisting of the new fronds or inflorescences which are soft and compactly folded as long, vertical semicylinders. It sometimes bores upward..... though not frequently, since the inner fronds of the crown grow faster than the outer ones. The beetle does not ingest the solid plant material, but sucks the juices that flow upward from the macerated cell tracts. It chisels with its mandibles by up and down motion of the head, rather than by chewing. In boring it also uses its clypeus horn and fore tibiae ..... The boring cuts off a frond, or it leaves large angular symmetrical gaps in the leaflets of one or more fronds, where the inner portion of the unopened frond is chewed, leaving the midrib." (See Plates 4 and 5).

The adult beetle produces a ragged appearance of the fronds which may be noticed either on one or both sides, depending on the severity of attack. Holes bored by the beetles at the base of the leaf stalks

*Plate 5*—Thirtyfive-year old palm damaged by the beetle.

*Plate 6*—Damaged bud of a 2 year old palm. The mode of boring is clearly seen. Note the deformed bud leaves displaying a crinkled appearance.

may eventually lead to the breaking of the frond in areas which are windy. The characteristic damage that is seen in coconut palms is the result of the beetles having bored through these portions of the palm whilst in the bud stage. The beetle forces its way down between the bases of the younger fronds and gouges an entrance into the tissue of the petiole. (See plate 6).

Several beetles may be found in one tunnel and it seems probable that the growing point can be reached only by the joint efforts of a number of beetles. If the growing point is killed, the palms assume a typical appearance of having older fronds but no young ones. Repeated attacks by a number of adults can result in the death of the palm.

**Flight Range.** It is reported by Nirula (1952) and O'Connor (1953) that the adult beetle is capable of long flights. Nirula reports that the beetles are capable of flights up to 100 yards.

## LIFE CYCLE STUDIES

**Techniques for Laboratory Rearing.** The eggs were placed in moist cow-dung (moisture content about 30-40 cent.) in a small glass bottle (see Plate 9) until they hatched. The larvae were then allowed to feed (see Plate 10).

*Plate 7*—Damaged unopened inflorescence.

*Plate 8 (a)*—Eventually when the spathes open, the spikelets have a ragged appearance.

*Plate 8 (b)*—Illustrating a greater degree of damage.

*Plate 9* (× 1½)—A single egg placed in sun-dried cowdung for hatching.

*Plate 10* (× 1½)—A freshly hatched larva.

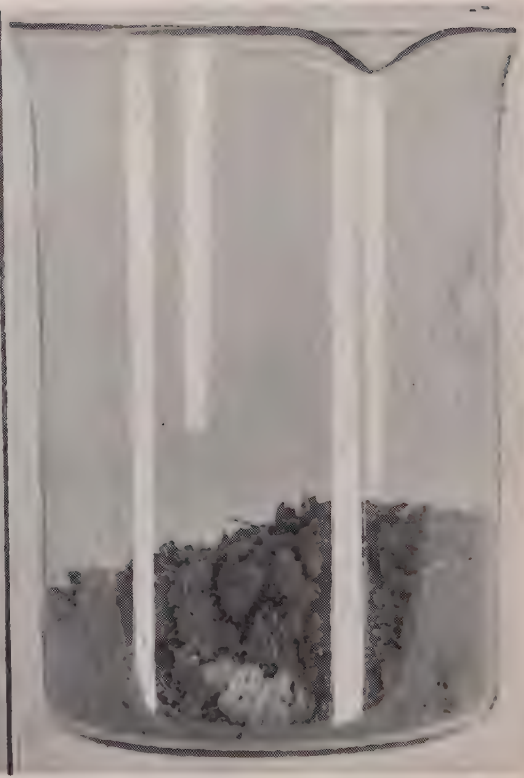

*Plate 11* —A second instar larva feeding on sundried cowdung.

*Plate 12*—A third instar larva in a 1 : 1 cowdung to soil mixture. Pupation takes place in this medium.

*Plate 13*—Adult beetle on emergence. The food material is coconut leaf petiole.

The food medium was renewed every second day. With the increase in size of the larvae they were transferred to beakers (see Plate 11). Prior to reaching the prepupal stage the larvae were given 1 : 1 mixture of cattle dung and soil. Pupation took place in this medium. On emergence from the cocoon the adults were introduced into a beaker covered with a 1 m.m. square wire gauze lid and given a piece of coconut leaf petiole to feed on. (see Plate 13). The adults were left to feed and oviposit. The food material was renewed every other day.

**The Egg.** The egg when freshly laid is oval and whitish. It measures 2-3 m.m. in breadth and 3-4 m.m. in length (see Plate 14). After incubation and prior to hatching the egg turns creamy yellow and increases to 5-6 m.m. in length and 4-5 m.m in breadth. Just prior to hatching, the embryo is occasionally visible within the egg.

*TABLE 1A—Freshly laid Eggs*

| *No.* | *Length* | *Breadth* |
|---|---|---|
| 1 .. .. | 3·0 m.m. | 2·0 m.m. |
| 2 .. .. | 3·5 m.m. | 2·0 m.m. |
| 3 .. .. | 3·0 m.m. | 2·5 m.m. |
| 4 .. .. | 4·0 m.m. | 2·0 m.m. |
| 5 .. .. | 3·5 m.m. | 3·0 m.m. |
| Average .. | 3·4 m.m. | 2·3 m.m. |
| Range .. | 3–4 m.m. | 2–3 m.m. |

*TABLE 1B—Eggs prior to hatching*

| | | |
|---|---|---|
| 1 .. .. | 5·5 m.m. | 4·0 m.m. |
| 2 .. .. | 6·0 m.m. | 3·5 m.m. |
| 3 .. .. | 5·0 m.m. | 3·0 m.m. |
| 4 .. .. | 5·5 m.m. | 3·5 m.m. |
| 5 .. .. | 5·0 m.m. | 5·0 m.m. |
| Average .. | 5·4 m.m. | 3·8 m.m. |
| Range .. | 5–6 m.m. | 3–5 m.m. |

**Fertility.** For this study thirty-one eggs collected from six different females in the field were used.

*Plate 14* (× *3*)—Freshly laid eggs placed in cowdung for hatching.

*Plate 15* (× *3*)—The egg on the left is undamaged. The other has been damaged by the mite *Parasitum heliocorpridis*.

*TABLE II*

| *No.* | *Date of laying* | *No. of eggs laid* | *No. of eggs hatched* |
|---|---|---|---|
| 1 .. | 17 January, 1957 | 10 | 0 |
| 2 .. | 5th December, 1956 | 9 | 8 |
| 3 .. | 8th January, 1957 | 1 | 0 |
| 4 .. | 6th May, 1957 | 1 | 1 |
| 5 .. | 9th January, 1957 | 9 | 1 |
| 6 .. | — | 1 | 1 |
| Average .. | | 5·22 | 1·8 |
| Range .. | | 1–10 | 1–8 |

The losses in hatching were caused by mites which suck the contents of the eggs leaving a crenated egg-shell (see Plate 15).

**Number of Eggs per Female.** In this study three laboratory-emerged females were used.

*TABLE III*

| *No.* | *Date of emergence* | *No. of eggs laid* | *Period in days during which eggs were laid* | *Average No. of eggs per day* | *Remarks (Eggs collected on the following days)* |
|---|---|---|---|---|---|
| 1 | 5th March, 1957 | 17 | 4 | 6 | 3rd, 5th and 6th May, 1957 |
| 2 | 19th March, 1957 | 14 | 7 | 5 | 5th, 10th and 11th June, 1957 |
| 3 | 14th March, 1957 | 27 | 10 | 5 | 6th, 7th, 9th, 10th 13th and 15th May, 1957 |
| | Average | 19·33 | 7 | 5 | |
| | Range | 14–27 | 4–10 | — | |

It will be seen from above that a single female will lay 14-27 eggs during her life span.

**The Larva.** The freshly hatched larva is yellowish white. The head capsule and the legs turn brown about 2 hours after emergence. In the second instar, the larvae are greyish. The larvae are full grown

*Plate 16* (× 3)—Recently hatched larvae. The one on the right is 2 hours old. It takes an average of 9 days to have its first moult.

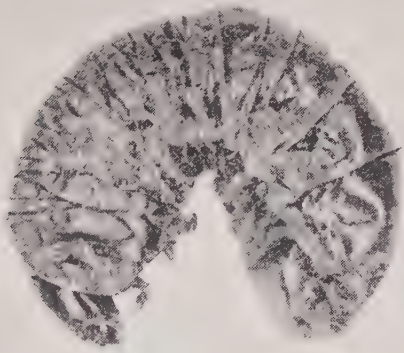

*Plate 17* (× 4)—A typical 2nd instar larva. Average duration of this instar is 18 days.

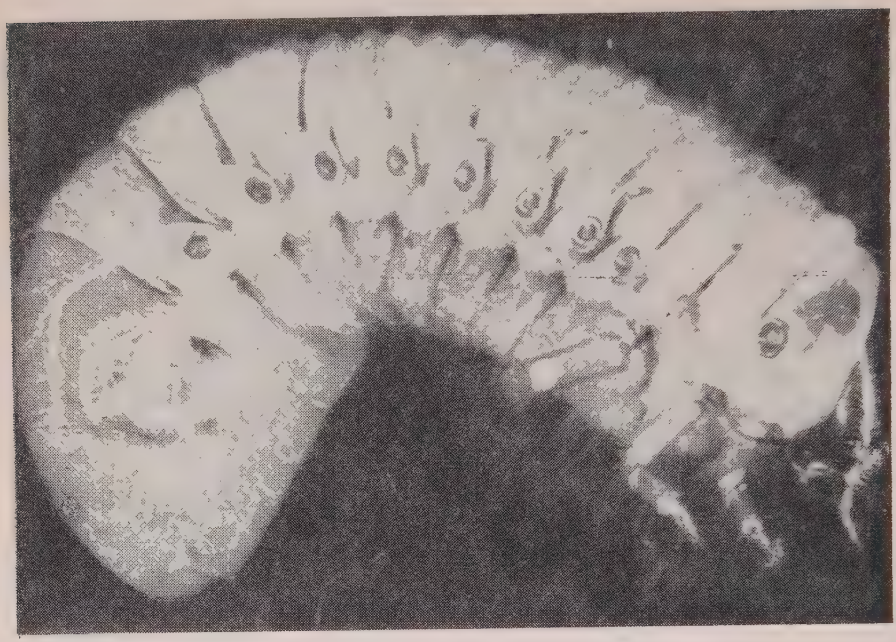

*Plate 18* (× 2½)—Third instar larva. Average duration of this instar is 85·12 days.

when they reach the 3rd instar. Their colour is ash grey and the body carries a large number of brown hairs or setae. The spiracles are seen on the pro-thoracic and in the 1st eight abdominal segments (see Plates 16, 17 and 18). The frontal portion of the head above the jaws is roughened and pitted. Small straight spines occur on the last abdominal segment. The anal slit is horizontal. No eyes are present.

Detailed findings of the instars and the rate of growth are given below :—

*TABLE IV*

| *No.* | *Length during 1st Instar* | *Length during 2nd Instar* | *Length during 3rd Instar* |
|---|---|---|---|
| 1 | 11 m.m. | 21 m.m. | 48 m.m. |
| 2 | 9 m.m. | 39 m.m. | 43 m.m. |
| 3 | 11 m.m. | 35 m.m. | 44 m.m. |
| 4 | 6 m.m. | 32 m.m. | 48 m.m. |
| 5 | 8 m.m. | 40 m.m. | 46 m.m. |
| 6 | 6 m.m. | 35 m.m. | 44 m.m. |
| 7 | 10 m.m. | 38 m.m. | 43 m.m. |
| Average | 8·7 m.m. | 34·2 m.m. | 45·1 m.m. |
| Range | 6–11 m.m. | 21–40 m.m. | 43–48 m.m. |

Measurements were taken on the 3rd day, after reaching the particular instar. It will be seen from the above figures that there is an overall increase in length of approximately 5 times that of the length on the 3rd day after hatching out.

**Duration of the Various Instars**. In Ceylon, under laboratory conditions, *Oryctes* have three instars prior to reaching prepupal stage. For this study eleven eggs were set up. The results are shown in Table V.

It is seen from the above figures that under laboratory conditions the larvae of *Oryctes* spent, on an average, 121 days in feeding, the range being 101-147 days. The longest period is that of the 3rd Instar which averages 85 days, the range being 72-103 days.

In this study egg No. 2 did not hatch out because it was infertile and the larva from egg No. 8 only lived until the completion of the first instar.

*Plate 19* (× *2*)—Prepupa. Average duration of the prepupal stage is 6 days.

*TABLE V*

| *No.* | *Date of egg laying* | *Date of hatching* | *No. of days for hatching* | *Date of 1st moult* | *No. of days for 1st Instar* | *Date of 2nd moult* | *No. of days for 2nd Instar* | *Date of 3rd moult* | *No. of days for 3rd Instar* |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 5th Dec., 56 | 12th Dec., 56 | 7 | 28th Dec., 56 | 16 | 13th Jan., 57 | 16 | 9th Apr., 57 | 86 |
| 2 | 5th Dec., 56 | — | — | — | — | — | — | — | — |
| 3 | 6th Dec., 56 | 16th Dec., 56 | 10 | 2nd Jan., 57 | 17 | 22nd Jan., 57 | 20 | 4th May, 57 | 103 |
| 4 | 6th Dec., 56 | 16th Dec., 56 | 10 | 1st Jan., 57 | 16 | 19th Jan., 57 | 18 | 24 Apr., 57 | 95 |
| 5 | 6th Dec., 56 | 16th Dec., 56 | 10 | 7th Jan., 57 | 22 | 26th Jan., 57 | 19 | 8th Apr., 57 | 72 |
| 6 | 6th Dec., 56 | 16th Dec., 56 | 10 | 2nd Jan., 57 | 17 | 18th Jan., 57 | 16 | 9th Apr., 57 | 81 |
| 7 | 6th Dec., 56 | 16th Dec., 56 | 10 | 2nd Jan., 57 | 17 | 19th Jan., 57 | 17 | 19th Apr., 57 | 90 |
| 8 | 6th Dec., 56 | 16th Dec., 56 | 10 | 29th Dec., 56 | 13 | — | — | — | — |
| 9 | 6th Dec., 56 | 16th Dec., 56 | 10 | 31st Dec., 56 | 15 | 20th Jan., 57 | 20 | 8th Apr., 57 | 78 |
| 10 | 6th Dec., 56 | ~~22nd Jan., 57~~ | 12 | 9th Feb., 57 | 18 | 2nd Mar., 57 | 21 | 25th May, 57 | 84 |
| 11 | 1st Dec., 56 | 8th Dec., 56 | 7 | 31st Dec., 56 | 23 | 18th Jan., 57 | 18 | 5th Jan., 57 | 77 |
| | Average | — | 8·72 | — | 15·8 | — | 18·34 | — | 85·12 |
| | Range | — | 7–12 | — | 13–23 | — | 16–21 | — | 72–103 |

**Pre-pupa and Pupal Period.** On completion of the third instar, the larvae reached prepupal stage (see Plate 19). In doing so the larvae stopped feeding and assumed a dull cream colour and became rather inactive.

When pupation is to take place the larvae generally seek shelter at the sides of the beaker and there construct earthen cells or cocoons for pupation. At the onset of these metamorphorsis from larval to pupal stage the larval skin splits down the back as is done in a moult. The skin so shed is pressed against the bottom of the shell thereby the pupa becoming free. (See Plate 20).

Pupation is three times as long as the prepupal period. Another study has been made with 44 field collected larvae that pupated. These had a pupal period averaging 21 days. Laboratory findings on the duration of the prepupal and pupal periods are given in Table VI.

*TABLE VI*

| *No.* | *Date of collection* | *Date of hatching* | *Date of end of 3rd Instar* | *Date of Pupation* | *Prepupal period in days* | *Date of emergence* | *Pupal period in days* |
|---|---|---|---|---|---|---|---|
| 1 | 5.12.56 | 12.12.56 | 9.4.57 | 16.4.57 | 7 | 5.5.57 | 19 |
| 2 | 5.12.56 | — | — | — | — | — | — |
| 3 | 6.12.56 | 16.12.56 | 4.5.57 | 10.5.57 | 6 | 28.5.57 | 18 |
| 4 | 6.12.56 | 16.12.56 | 24.4.57 | 29.4.57 | 5 | 15.5.57 | 16 |
| 5 | 6.12.56 | 16.12.56 | 8.4.57 | 12.4.57 | 4 | 29.4.57 | 17 |
| 6 | 6.12.56 | 16.12.56 | 9.4.57 | 16.4.57 | 7 | 7.5.57 | 21 |
| 7 | 6.12.56 | 16.12.56 | 19.4.57 | 25.4.57 | 6 | 11.5.57 | 17 |
| 8 | 6.12.56 | 16.12.56 | — | — | — | — | — |
| 9 | 6.12.56 | 16.12.56 | 8.4.57 | 15.4.57 | 8 | — | — |
| 10 | 10. 1.57 | 22. 1.57 | 25.5.57 | 2.6.57 | 8 | 21.6.57 | 19 |
| 11 | 1.12.56 | 8.12.56 | 5.4.57 | 10.4.57 | 5 | 26.4.57 | 16 |
| Average | | | | | 6 | | 17·9 |
| Range | | | | | 4–8 | | 16–21 |

**The Adult.** Once the metamorphosis had taken place, the cocoons ruptured and the creamy white adults were exposed. Within 24 hours, the adult acquired a natural black colour. It was observed that the newly formed adult remains in the pupal cocoons for a period of 17 to 22 days, prior to emergence.

*Plate 20* (× 1½)—Intact ~~imago~~ pupa on the left and a longitudinally sectioned cocoon on the right exposing the ~~imago~~ pupa. Average duration of pupation is 18 days.

Table VII gives the details of these findings.

*TABLE VII*

| *No.* | *Date of hatching* | *Date of emergence* | *Pupal period in days* | *Sex* |
|---|---|---|---|---|
| 1 | 12th December, 1956 | 5th May, 1957 | 19 | Male |
| 2 | — | — | — | — |
| 3 | 16th December, 1956 | 28th May, 1957 | 18 | Female |
| 4 | 16th December, 1956 | 15th May ,1957 | 16 | Male |
| 5 | 16th December, 1956 | 29th April, 1957 | 17 | Male |
| 6 | 16th December, 1956 | 7th May, 1957 | 21 | Female |
| 7 | 16th December, 1956 | 11th May, 1957 | 17 | Male |
| 8 | 16th December, 1956 | | — | — |
| 9 | 16th December, 1956 | — | — | — |
| 10 | 21st January, 1957 | 21st June, 1957 | 19 | Male |
| 11 | 8th December, 1956 | 26th April, 1957 | 16 | Male |
| Average | — | — | 17·9 | |
| Range | — | — | 16–21 | |

**Period of Adult Life.** To study the span of adult life five adult beetles were observed ; two of these adults were raised from eggs and three

emerged from field collected larvae. The results obtained were as follows :—

*TABLE VIII*

| *No.* | *Date of emergence* | *Date of death* | *Adult period in days.* |
|---|---|---|---|
| 1 | 6th March, 1957 | 20th May, 1957 | 75 |
| 2 | 10th March, 1957 | 24th June, 1957 | 106 |
| 3 | 14th March, 1957 | 18th May, 1957 | 65 |
| 4 | 27th May, 1957 | 27th August, 1957 | 112 |
| 5 | 28th May, 1957 | 24th August, 1957 | 88 |
| Average | — | — | 89·2 |
| Range | — | — | 65–112 |

**Description of the Adult.** The adult is a large shiny beetle, black on the dorsal surface, and reddish brown on the ventral side. It is on an average 37.5 m.m. to 40 m.m. in length, and about 20 m.m. in width. The head is small and carries on it a stout horn which is either short and triangular in the female, or long and curved in the male. The male has a longer horn than the female. In the female the last abdominal segment or pygidium is densely covered with setae. This abdominal segment in the male is smooth and bare with only one or two setae running across the upper portion. Generally the ventral surface of the abdomen of the male is clothed to a less extent by setae than that of the female. (See Plate 21).

The mandibles are strong and the antennae have lamentate clubs. Setae are found on the legs. The elytra are finely striate.

*Plate 21* (× 1½)—Adult beetles. The male is the larger one of the two.

*TABLE IX*

| *No.* | *Date of emergence* | *Date of 1st laying* | *No. of days emergence 1st laying* | *Date of last laying* | *No. of days emergence to last laying* | *No. of eggs collected* | *Date of death* | *Adultperiod in days* |
|---|---|---|---|---|---|---|---|---|
| 1 | 6th March, 1957 | 3rd May, 1957 | 58 | 6th May, 1957 | 61 | 17 | 20th May, 1957 | 75 |
| 2 | 10th March, 1957 | 5th June, 1957 | 87 | 11th June, 1957 | 93 | 14 | 24th June, 1957 | 106 |
| 3 | 14th March, 1957 | 6th May, 1957 | 53 | 15th May, 1957 | 62 | 27 | 18th May, 1957 | 65 |
| 4 | 7th May, 1957 | 31st July, 1957 | 86 | 23rd August, 1957 | 109 | 16 | 27th August, 1957 | 112 |
| 5 | 28th May, 1957 | — | — | — | — | — | 24th August, 1957 | 88 |
| | Average | | 71 | | 81·3 | 18·5 | | 89·2 |
| | Range | | 53–87 | | 61–109 | 14–27 | | 65–112 |

An adult takes on an average of 71 days after emergence before egg laying takes place for the first time, the range being 53–87 days. The final egg laying takes place on an average of 8 days– the range being from 7–12 days.

No significant difference between precedence of death between male and female was observed. In some instances the male preceded the female by a day or so and in other instances the female preceded the male.

## SUMMARY

Laboratory findings at the Coconut Research Institute, Ceylon, are as follows :—

A single female of *Oryctes* can lay an average of 18.5 eggs if fed on coconut petiols, the range being 14–27 eggs. The mean dimensions of the egg at laying are 3.4 m.m. in length and 2–3 m.m. in breadth, the range being 3–4 m.m. and 2–3 m.m. respectively. Just prior to hatching the eggs swell up to nearly twice their size. The average dimensions are 5.4 in length and 3.8 m.m. in breadth, the range being from 5–6 m.m. and 4–5 m.m. respectively. A single female laid 5 to 6 eggs per day over a period of 4 to 6 days. Fertility of eggs may be as high as 90 per cent.

The different instars of the larvae are characterised by size and colour. At birth the larvae measure on an average of 8.7 m.m., the range being 6–11 m.m. Towards the end of the 3rd instar, the larvae measured an average of 45.1 m.m., the range being 43–48 m.m. i.e. there is a five-fold increase in size of the larvae from birth to the 3rd instar. The larvae are yellowish white at birth, greyish during the 2nd instar and ash grey in 3rd instar. To complete the period from egg to 3rd instar, it takes an average of 130 days, the range being 108–149 days.

The average duration of the pre-pupal period is 6 days (range 4–8 days) and of the pupal period 18 days (range 16–21 days). An average of 155 days intervenes between the egg and completion of the pupal period, the range being from 128–178 days.

The completion of the adult life (i.e. from emergence to death) takes an average of 89 days, the range being 65–112 days.

The completion of one generation of *Oryctes* i.e. egg to death, occupies an average of 244 days, the range being 193-293 days.

The studies also revealed that :—

(*a*) *Oryctes* is monogamous,

(*b*) Moisture is a critical requirement for the successful completion of the life cycle, particularly in the pupal stage,

(*c*) In Ceylon, field-collected larvae are either infected with disease or are carriers of disease.

(*d*) Coconut leaf petiole is a better source of food for the adult than sugar cane.

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# BOOK REVIEW

**Physics and Chemistry of Life—A Scientific American Book XI—267 pp. G. Bell & Sons Ltd. London. 13s. 6d.**

This is a collection of eighteen articles on various aspects of life written by some of the leading workers in these fields of study. They appeared at different times in the Scientific American and are written in as non-technical English as possible. The articles present to the reader the rapid progress made in our knowledge regarding fundamental problems of life.

For quite some time attempts have been made to explain life processes in terms of Physics and Chemistry, but it has always been difficult to explain some of the processes like growth and reproduction. The fact that George Wald could now speculate on the origin of life is in itself an indication of the extent of the progress made in the allied fields of study. In the first chapter he discusses how living material is built up from simple molecules of non-living matter. After a brief reference to the complexity of organic compounds, like carbohydrates, fats, proteins and nucleic acids, and to their endless variety, he discusses the possibilities of spontaneous generation. He refers to the spontaneous production of particular types of biological structure by protein molecules as seen under the electron miscroscope. He observes that the aggregates of molecules can arrange themselves into different patterns and that, given the right molecules, they can do a great deal for themselves.

The chapters that follow give us in some detail the nature of the evidence.

Rabinowitch deals with photosynthesis, a process by which the energy of the sunlight is stored as chemical energy in the organic compounds, which are ultimately used by all living organisms. It is not generally realised that nearly 90 per cent of the total amount of carbon compounds synthesised is carried out by mocroscopic algae of the oceans. He refers to the new techniques available to the biologist now, like the use of tracer istopes and paper chromatography which have helped us to understand much of the mechanism of photosynthesis. However, in spite of all this knowledge it has not been possible for man to duplicate the process in the laboratory.

In the next article Kamen deals with nitrogen fixation and its importance to all forms of life. He describes the accidental discovery of the capacity of other so far unsuspected organisms, like purple bacteria, to fix nitrogen and to produce the precursors of proteins. Chemical analyses and X'Ray diffraction techniques have supplied information regarding the structure of the protein molecule, which Fruton describes as " the noblest piece of architecture produced by nature ".

The next step naturally is reproduction, and in the process the transmission of hereditary material.

Mirsky reviews the work on the chemistry of heredity. Desoxyribonucleic acid (DNA) is peculiar to the chromosomes, while ribose nucleic acid (RNA) is found in the cytoplasm. The decisive influence of the nucleus on the cell is regarded by some workers as being due to the fact that RNA is produced in the nucleus and passes out into the cytoplasm. The very illuminating work initiated by Griffith on pneumococci, later confirmed and extended at the Rockefeller Institute, demonstrated the capacity of DNA of one strain to produce heritable changes in another.

X'Ray diffraction pictures have shown DNA to be wound as a double helix. Crick shows how the structure of DNA endows it with the property to reproduce itself.

Therafter the viruses come for consideration. They are important as animal and plant pathogens. But they are of interest at this juncture because of their simplicity. Outside the cell it is nothing more than a nucleo-protein. Are they then living or non-living ?

Similarly the Rickettsiae, the cause of human disease, is interesting as it lies in a realm intermediate between bacteria and viruses. Like the viruses they can grow only on living tissue. But they can oxidise compounds of the citric acid cycle, and in this respect are like the mitochondria. DNA is found in Rickettsiae and not in mitochondria. Are the Rickettsiae evolved from mitochondria and the viruses from genes ? Or do the viruses, Rickettsiae and bacteria represent an evolutionary series of increasing complexity as evidenced by their gradation in size and chemical complexity ? Or are the Rickettsiae evolved from bacteria and the viruses from Rickettsiae by increasing loss of enzymes as a result of parasitic mode of life ? In short, do the viruses represent the origins of life or are they end products of a line of retrogressive evolution ?

The short chapter on genes of men and molds gives some account of the very interesting results obtained from the work on the bread mold, *Neurospora.* The idea that the genes exert their effects via the

enzymes is examined. The break down of carbohydrates by enzymes releases free energy which is locked up as chemical energy in the high energy phosphate compounds—e.g., adenosine triphosphate (ATP). The role of ATP in metabolism is fully explained in the chapter on the metabolism of fats.

The penultimate chapter deals with cell division and cell differentiation, the latter being probably the least understood problem in Biology. All organisms orginate from a single cell (the fertilized egg) with a single nucleus, yet very soon the different cells produced by the division of this cell give entirely different structures. Do all the structures exist in miniature in the cell ? Or are the organs formed by gradual interaction of the constituents of the egg by what Aristotle called "epigenesis" ? Waddington makes a critical analysis of the evidence available.

The last chapter deals with muscle, nerve and brain, about the development of electroencephalagraphy and the use of cathode ray tubes for the study of personality.

Though the book is a collcetion of separate articles written by different authors, the chapters are so arranged that they make a well-knit story. The book is of absorbing interest and should appeal to all those who take any interest in scientific topics.

B. L. T. DE S.

# METEOROLOGICAL REPORT

## Summary for January—March, 1958

Ordinary north-east monsoon weather prevailed over the Island during January. The rainfall was mainly confined to the north-eastern hill-country, where it was experienced almost daily, except during the period, 16th to 22nd. The rainfall was fairly heavy and widespread during the first 3 days and the last 5 days of the month. On days of weak monsoon conditions, afternoon and evening thundershowers were experienced in the south-western parts. These were appreciably heavy on the 13th and 30th. The greater monthly totals (which occourred in the north-eastern hill-country) ranged from 15 to 30 inches. Elsewhere in the north-eastern parts as well as in the south-west quarter the rainfall was mainly of the order of 5 to 10 inches. Least rain was experienced in the north-western parts, in Jaffna Peninsula and in the neighbourhood of Hambantota, where the monthly totals were below 2 inches. The rainfall was appreciably below normal in the north-eastern parts, where the greater deficits ranged generally from 5 to 10 inches. The rainfall was about average in the south-western parts, with some appreciable excesses in the south-western mid-country.

The month commenced with widespread moderate rain on the 1st. Thereafter, for two weeks, the weather was mostly dry. Some monsoon rain was experienced on the 16th and 17th, followed by a period of scattered thundershowers lasting till the 26th. These rains were confined mainly to the south-western mid-country. The weather was dry again on the last two days of the month. A major portion of the Island received less than 2 inches of rain for the month. Greater totals (which ranged from 5 to 10 inches) occurred, in the north-eastern hill-country, in the neighbourhood of Kalmunai and in the south-western low and mid-country, the Hiniduma-Kalawana area receiving over 10 inches. The rainfall was generally above normal in the south-western parts and, in places in Batticaloa District and the north-eastern hill-country, while it was below normal elsewhere.

During March there were to periods of wet weather resulting from afternoon or evening thunder activity, one lasting from the 9th to 16th and the other from the 22nd to 27th. Fairly widespread rain was experienced during both these periods, with moderately heavy falls

on some days. The weather was mostly dry during the rest of the month, except on the 29th and 30th, on which days too, some evening thundershowers were experienced in the south-western parts. This rainfall was mainly confined to Sabaragamuwa Province and neighbourhood, where several stations recorded monthly totals over 20 inches. Elsewhere in the south-western parts as well as in the hill-country the rainfall ranged from 5 to 15 inches. Least rain, with totals below 2 inches occurred along the north-east coast and in the neighbourhood of Hambantota. The rainfall was well above normal in Sabaragamuwa Province and Kurunegala District, and among and around the central hills, the greater excesses being mainly of the order of 5 inches. The rainfall was below normal in the south-eastern parts and in the eastern and north eastern coastal regions.

D. T. E. DASSANAYAKE,
Director of Meteorology.

| | JANUARY | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Temperature | | | | Humidity | | Rainfall | | |
| | Mean Maximum | Offset | Mean Minimum | Offset | Day | Night (from Min. Temp s.) | Total | Offset | Number of days |
| Anuradhapura .. | 84·8 | +1·4 | 71·0 | +1·8 | 78 | 95 | 2·44 | —3·36 | 16 |
| Badulla .. | 77·6 | +1·4 | 65·8 | +2·0 | 82 | 95 | 5·83 | —4·49 | 21 |
| Batticaloa .. | 82·7 | +1·2 | 74·9 | +1·3 | 82 | 90 | 8·93 | —3·95 | 16 |
| Colombo .. | 87·2 | +0·8 | 73·6 | +1·8 | 72 | 88 | 2·88 | —1·08 | 8 |
| Diyatalawa .. | 73·4 | +1·6 | 59·9 | +2·2 | 84 | 94 | 4·06 | —2·58 | 5 |
| Galle .. .. | 84·6 | +0·8 | 74·3 | +1·3 | 76 | 86 | 5·08 | +1·20 | 10 |
| Hambantota .. | 85·5 | +0·6 | 74·4 | +1·7 | 78 | 90 | 1·17 | —2·83 | 8 |
| Jaffna .. .. | 84·3 | +1·3 | 75·2 | +3·1 | 68 | 77 | 1·90 | —2·51 | 4 |
| Kandy .. | 83·6 | +1·5 | 67·1 | +2·1 | 74 | 92 | 2·28 | —4·46 | 14 |
| Kankesanturai .. | 84·3 | +1·5 | 75·8 | +0·9 | 73 | 82 | 0·76 | —2·65 | 4 |
| Kurunegala .. | 87·5 | +1·1 | 70·8 | +0·9 | 68 | 95 | 0·70 | —4·41 | 7 |
| Mannar .. | 84·2 | +0·9 | 76·3 | +2·1 | 73 | 82 | 1·06 | —2·78 | 5 |
| Nuwara Eliya .. | 69·7 | +1·9 | 50·5 | +3·4 | 78 | 87 | 4·67 | —2·29 | 14 |
| Puttalam .. | 87·3 | +1·8 | 71·7 | +1·7 | 71 | 90 | 2·02 | —1·41 | 12 |
| Ratmalana .. | 88·0 | +1·1 | 73·4 | +2·0 | 70 | 88 | 0·83 | —3·32 | 7 |
| Ratnapura .. | 91·0 | +1·8 | 72·2 | +1·0 | 67 | 90 | 6·51 | +0·25 | 12 |
| Talawakele .. | 73·9 | —0·3 | 57·7 | +2·2 | 75 | 85 | 3·94 | +0· 7 | 12 |
| Trincomalee .. | 82·1 | +1·6 | 77·3 | +2·0 | 76 | 80 | 5·10 | —3·21 | 12 |

FEBRUARY

| | Temperature | | | | Humidity | | Rainfall | | |
|---|---|---|---|---|---|---|---|---|---|
| | Mean Maximum | Offset | Mean Minimum | Offset | Day | Night (from Min. Temps.) | Total | Offset | Number of days |
| Anuradhapura .. | 88·8 | +1·6 | 71·1 | +1·8 | 69 | 95 | 1·32 | —0·40 | 3 |
| Badulla .. | 80·8 | +1·8 | 63·7 | +0·5 | 70 | 91 | 1·76 | —1·41 | 7 |
| Batticaloa .. | 83·7 | +0·8 | 74·5 | +0·8 | 78 | 93 | 4·06 | —0·15 | 9 |
| Colombo .. | 86·0 | —1·1 | 72·8 | +0·8 | 73 | 90 | 6·94 | +4·34 | 5 |
| Diyatalawa .. | 77·3 | +2·4 | 58·1 | +1·2 | 70 | 88 | 1·08 | —1·29 | 9 |
| Galle .. .. | 85·3 | +0·2 | 74·7 | +1·1 | 74 | 88 | 6·36 | +3·07 | 6 |
| Hambantota .. | 86·3 | +0·4 | 74·2 | +1·2 | 77 | 90 | 0·78 | —0·68 | 4 |
| Jaffna .. .. | 86·6 | +1·0 | 73·7 | +1·5 | 66 | 84 | 0·19 | —1·27 | 1 |
| Kandy .. | 86·5 | +1·1 | 65·6 | +1·3 | 63 | 92 | 0·52 | —1·87 | 5 |
| Kankesanturai .. | 86·3 | +1·6 | 73·8 | —0·2 | 69 | 88 | 0 | —1·08 | 0 |
| Kurunegala .. | 91·5 | +1·6 | 70·6 | +0·9 | 59 | 95 | 0·17 | —1·82 | 4 |
| Mannar .. | 86·5 | +0·4 | 74·9 | +1·1 | 70 | 88 | 0·14 | —1·56 | 1 |
| Nuwara Eliya .. | 71·1 | +1·5 | 48·2 | +2·9 | 69 | 83 | 1·55 | —0·44 | 7 |
| Puttalam .. | 88·3 | 0 | 71·7 | +1·5 | 68 | 90 | 0·35 | —1·02 | 4 |
| Ratmalana .. | 87·5 | +0·1 | 72·9 | +1·4 | 71 | 93 | 2·31 | —1·05 | 8 |
| Ratnapura .. | 92·1 | +0·6 | 72·1 | +0·7 | 64 | 88 | 8·73 | +3·43 | 6 |
| Talawakele .. | 74·7 | —1·7 | 55·5 | +1·0 | 71 | 82 | 0·89 | —1·08 | 6 |
| Trincomale .. | 84·6 | +2·1 | 76·1 | +0·8 | 73 | 84 | 2·00 | —0·65 | 3 |

MARCH

| | Temperature | | | | Humidity | | Rainfall | | |
|---|---|---|---|---|---|---|---|---|---|
| | Mean Maximum | Offset | Mean Minimum | Offset | Day | Night (from Min. Temps.) | Total | Offset | Number of days |
| Anuradhapura .. | 91·6 | +0·1 | 73·3 | +1·7 | 69 | 95 | 5·80 | +1·65 | 9 |
| Badulla .. | 82·9 | +0·5 | 65·4 | +1·1 | 71 | 92 | 8·07 | +3·02 | 15 |
| Batticaloa .. | 85·9 | +0·5 | 75·9 | +0·8 | 77 | 93 | 2·82 | —0·65 | 11 |
| Colombo .. | 87·8 | 0 | 74·9 | +0·9 | 73 | 92 | 5·13 | +0·47 | 9 |
| Diyatalawa .. | 79·2 | +1·6 | 59·0 | +0·8 | 72 | 91 | 6·11 | +1·22 | 12 |
| Galle .. .. | 86·5 | +0·2 | 75·1 | +0·1 | 73 | 86 | 5·87 | +0·56 | 12 |
| Hambantota .. | 88·3 | +1·4 | 75·7 | +1·4 | 73 | 88 | 0·66 | —2·73 | 5 |
| Jaffna .. .. | 88·7 | 0 | 77·6 | +1·7 | 68 | 84 | 3·45 | +1·87 | 8 |
| Kandy .. | 87·5 | —0·4 | 68·6 | +1·5 | 69 | 95 | 10·27 | +4·85 | 15 |
| Kankesanturai .. | 89·7 | +1·0 | 76·8 | +1·5 | 70 | 91 | 1·19 | —0·28 | 5 |
| Kurunegala .. | 92·3 | —0·3 | 73·2 | +1·2 | 66 | 93 | 18·29 | +12·01 | 12 |
| Mannar .. | 90·9 | —0·7 | 72·0 | +0·4 | 69 | 95 | 5·59 | +0·95 | 10 |
| Nuwara Eliya .. | 89·8 | +0·5 | 77·3 | +1·9 | 70 | 86 | 1·48 | —0·36 | 7 |
| Puttalam .. | 71·9 | +1·0 | 49·1 | +2·6 | 69 | 81 | 5·83 | +1·74 | 13 |
| Ratmalana .. | 90·4 | +0·5 | 74·0 | +1·1 | 68 | 90 | 4·17 | +1·09 | 13 |
| Ratnapura .. | 89·1 | +0·9 | 74·5 | +0·7 | 69 | 90 | 7·11 | +0·63 | 11 |
| Talawakele .. | 93·0 | +0·9 | 72·8 | +0·3 | 66 | 88 | 8·03 | —2·35 | 16 |
| Trincomalee .. | 88·1 | +2·5 | 77·9 | +1·? | 71 | 84 | 1·47 | —0·83 | 8 |